QUALITY ASSURANCE PROJECT PLAN

Grass Lawn Park
Low Impact Development Monitoring

Prepared for

City of Redmond, Department of Public Works

April 2008

QUALITY ASSURANCE PROJECT PLAN

Grass Lawn Park
Low Impact Development Monitoring

City of Redmond
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April 15, 2008

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Introduction

Stormwater runoff from impermeable surfaces, such as pavement and rooftops, often contains high levels of pollutants including suspended solids, heavy metals, and petroleum products. In addition, concentrated runoff from impermeable surfaces can increase erosion in nearby streams. In the past, these problems were typically mitigated through the construction of end-of-pipe detention facilities that attenuate flows and promote sedimentation and biological processes to improve water quality. More recently, the concept of low impact development (LID) has become widely accepted as a potentially superior method for treating stormwater runoff. LID measures focus on the infiltration of water as close as possible to its point of origin to prevent it from concentrating in downgradient areas and ultimately producing large quantities of surface runoff that are difficult and costly to treat. Recognizing the potential benefits of LID treatment practices, the Washington State Department of Ecology (Ecology) established a grant program to fund LID projects sponsored by local agencies.

In 2006, The City of Redmond applied for and received an Ecology LID grant to help fund the renovation of a 2-acre section of the 28.5-acre Grass Lawn Park (Figure 1). Located near the northwest corner of 148th Avenue NE and Old Redmond Road, the park was initially developed in 1978 and currently contains two parking lots, two basketball courts, three softball fields, one soccer field, asphalt sidewalks, six tennis courts, a picnic shelter, and restrooms. Planned renovation of the park will include a new pavilion, maintenance building, play areas, and walking paths. Pursuant to the grant scope of work from Ecology, these renovations will include several LID features, including a permeable pavement basketball court, permeable pavement sidewalks, a dispersion trench, rain gardens, soil amendment, and a vegetated roof on the new maintenance building.

The grant scope of work also requires that a monitoring program be implemented to evaluate flow quantity reductions and the level of water quality treatment that will be realized through these LID features. In connection with this monitoring program, a Quality Assurance Project Plan (QAPP) must be prepared to provide detailed information on the monitoring approach and laboratory protocols, including types of data and samples to be collected, sample locations, sampling frequency, sampling procedures, analytical methods, quality control procedures, data handling protocols, and data assessment procedures. Following Ecology's review and approval of the QAPP, the associated monitoring will be initiated after construction of the LID features and extend over a 3-year period.

This document is the QAPP as required by the grant scope of work. It describes monitoring procedures that will be used to document: (1) the performance of flow control (i.e., reductions in runoff quantity) associated with both the permeable pavement basketball court and vegetated roof features, and (2) the performance of water quality treatment provided by the vegetated roof. This QAPP was prepared based on guidance presented in Ecology's *Guidelines and Specifications for Preparing Quality Assurance Project Plans* (Ecology 2004) and includes the following major sections:

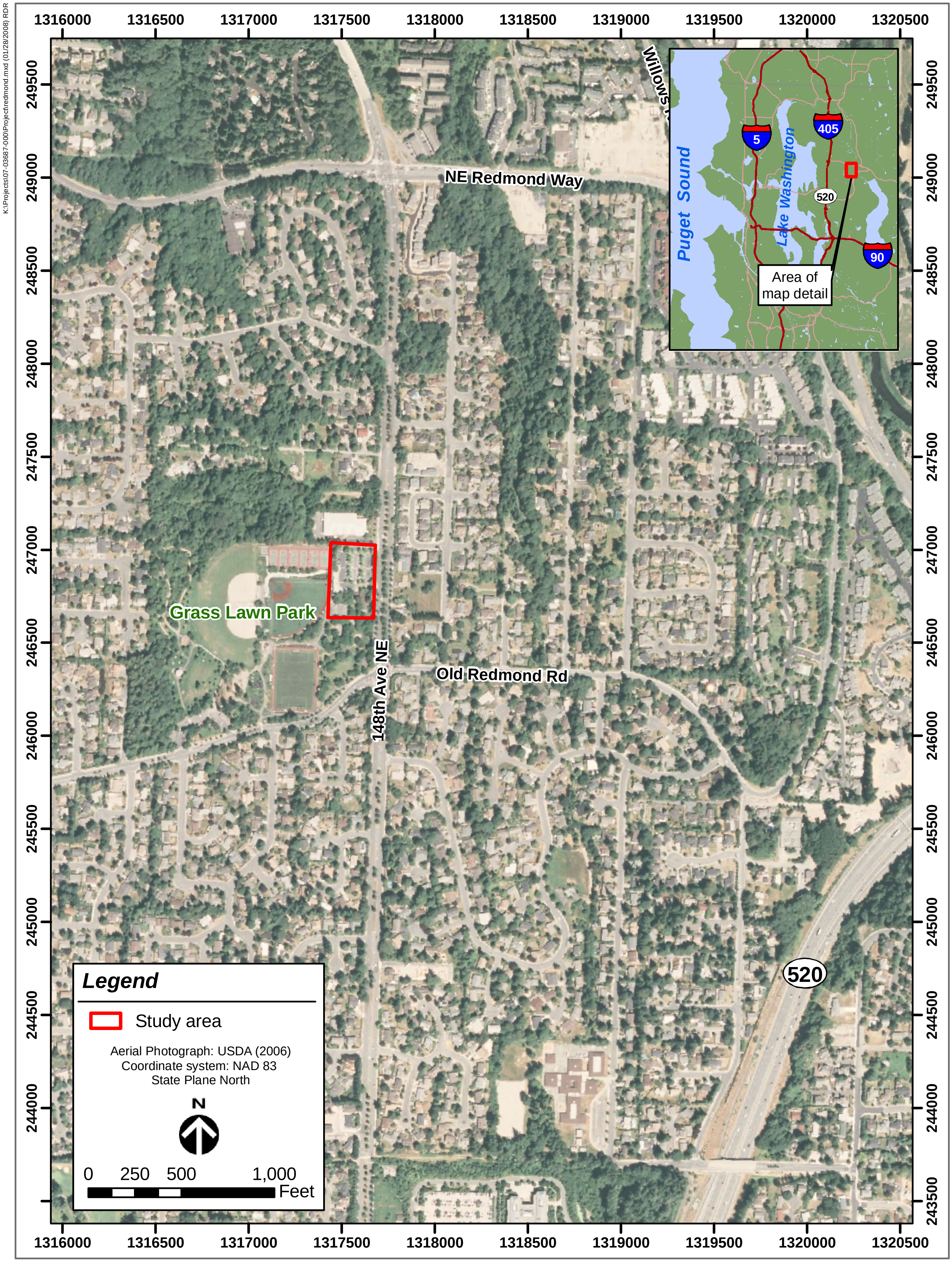

Figure 1. Vicinity map for the Grass Lawn Park low impact development monitoring study.

- Background
- Project Description
- Organization and Schedule
- Quality Objectives
- Sampling Process Design
- Sampling Procedures
- Measurement Procedures
- Quality Control
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Background

Stormwater flow control has traditionally focused on end-of-the-pipe solutions, where flow is routed from impermeable surfaces via curbs, drains, and pipes to a structural best management practice (BMP) facility. These facilities (generally a pond, vault, or swale) are designed to attenuate and/or infiltrate flows to decrease the resultant discharge rates. However, recent research (Booth et al. 2002) has suggested that traditional stormwater BMPs may not be performing up to the expected standards. In addition, numerous studies have indicated that biofiltration practices (which are common elements of low impact development) offer superior pollutant treatment (Barrett 2005; Strecker et al. 2004) and runoff reduction (Dietz 2007). By mimicking the hydrological processes that occur with predevelopment land use, low impact development reduces both the rate and volume of peak flows. In areas characterized by an increase in impermeable surface, this can only be accomplished by increasing stormwater infiltration in those adjacent areas that remain permeable. Alternatively, practitioners may choose to install permeable analogs to traditional impermeable surfaces; these structures include permeable pavement systems and vegetated roofs (also called green roofs).

Vegetated roofs have been shown to retain an average of 63 percent of influent rainfall (Dietz 2007), while permeable pavement systems have been shown to reduce surface runoff by as much as 93 percent (Dreelin et al. 2006) compared to traditional paving. Results such as these have contributed to an increasing interest in the use of LID features for treating stormwater runoff across the United States. In recognition of the growing importance of LID, Ecology established an LID grant program in 2006 and has awarded $2,500,000 in grant money to local governments within the Puget Sound area. This financial assistance will help local governments meet critical stormwater management needs that protect and restore water quality while encouraging the adoption of LID features.

The City of Redmond (the City) applied for and received a grant to add LID features to renovations at Grass Lawn Park. This community park is located at the intersection of 148th Avenue NE and Old Redmond Road (Figure 1). The City is currently renovating approximately 2 acres of the park to add a new pavilion, maintenance building, play areas, and walking paths. Using the money obtained from Ecology's LID grant program, the City is incorporating several LID features into the park's renovation, including a vegetated roof on the new maintenance building, compost-amended soils, tree retention and planting, open channel conveyance of stormwater, permeable pavement sidewalks, and a permeable pavement basketball court.

Ecology's grant award stipulates that a monitoring program be implemented to evaluate flow quantity reductions and the level of water quality treatment that will be realized through these LID features. In connection with this monitoring program, a QAPP must be prepared to provide detailed information on the monitoring approach and laboratory protocols. The City of Redmond contracted Herrera Environmental Consultants, Inc. (Herrera) to design a monitoring program, prepare this QAPP, and implement the monitoring program. The preparation and implementation of this QAPP are designed to satisfy the grant requirements. Ecology (as well as the scientific and engineering community-at-large) will ultimately use these monitoring results to inform the design and construction of future LID projects in western Washington.

Project Description

The goal of this monitoring project is to increase the understanding of the stormwater treatment performance of permeable pavement systems and vegetated roofs. The knowledge gained from this project will be used by regional practitioners to inform the future application and design of these LID features. To meet this goal, the following objectives have been defined for this project:

- Evaluate the annual volume and peak flow reduction achieved through the application of permeable pavement systems
- Evaluate the annual volume and peak flow reduction achieved through the application of vegetated roofs
- Compare pollutant concentrations in roof runoff from a traditional (metal) roof relative to a vegetated roof.

To meet these objectives, the experimental design for this project involves the continuous monitoring of runoff volumes from an impermeable pavement basketball court and a permeable pavement basketball court in Grass Lawn Park. Continuous monitoring of runoff volumes will also be performed in association with a traditional roof and a vegetated roof that are located on a park pavilion and maintenance building, respectively. The water quality of runoff from the traditional and vegetated roofs will also be evaluated based on grab samples collected during discrete storm events and analyzed for common pollutants.

Data loggers will be located in locked closets within a maintenance building and pavilion in the Park. Gauges will be located in catch basins. This configuration discourages vandalism and assures the security of the monitoring equipment. Herrera was in consultation through the construction phase of the project; consequently, practical constraints on monitoring were addressed and remedied before final construction of the LID features and water conveyance systems. Monitoring is scheduled to begin in March 2008 and continue over a 3-year period, extending through March 2011.

Organization and Schedule

Key project participants are identified and listed below, followed by the schedule for project implementation.

Project Organization and Key Personnel

As described above, this study is being conducted to characterize the stormwater treatment benefit(s) of LID features at Grass Lawn Park in Redmond, Washington. The City of Redmond Department of Public Works and Natural Resources will oversee the project. Herrera Environmental Consultants, Inc. (Herrera) is responsible for developing and implementing this QAPP. Key personnel involved in this effort are identified below, with their respective roles:

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Project Budget

The renovations at Grass Lawn Park include the construction of a new maintenance building, a pavilion, new pervious sidewalks and resurfaced basketball court, conversion of a impervious basketball court to a pervious asphalt basketball court, construction of a vegetated roof, and many other features. It is estimated that the total cost of this project will amount to $1,869,000, of which $469,200 will be granted by Ecology. It is estimated that the monitoring component of this project will amount to $89,981. A detailed budget is provided in Appendix A.

Project Schedule

Monitoring associated with this study is scheduled to begin in March 2008 and continue through March 2011. Reporting for this project will be organized to evaluate and present the results of data collected during this monitoring period. In keeping with this schedule, the following project milestones have been identified:

- January 2008—Draft quality assurance project plan submitted to City of Redmond
- February 2008—Draft quality assurance project plan submitted to Ecology
- April 2008—Final quality assurance project plan completed
- May 2008—Monitoring equipment installation
- June 2008—Start of monitoring
- January 30, 2009—Semiannual data report and quality assurance memorandum submitted to City of Redmond
- June 30, 2009—Semiannual data report and quality assurance memorandum submitted to City of Redmond

- January 30, 2010—Semiannual data report and quality assurance memorandum submitted to City of Redmond
- June 30, 2010—Semiannual data report and quality assurance memorandum submitted to City of Redmond
- January 30, 2011—Semiannual data report and quality assurance memorandum submitted to City of Redmond
- June 30, 2011—Semiannual data report and quality assurance memorandum submitted to City of Redmond
- July 2011—Monitoring terminated
- September 15, 2011—Draft final data report submitted to City of Redmond
- October 30, 2011—Final data report submitted to City of Redmond and Ecology.

Quality Objectives

A primary purpose of this QAPP is to ensure that the data collected for this study are scientifically and legally defensible. Therefore, the collected data will be evaluated relative to the following indicators of quality assurance:

- Precision: A measure of the variability in the results of replicate measurements due to random error.
- Bias: The systematic or persistent distortion of a measurement process that causes errors in one direction (i.e., the measured mean is different from the true value).
- Representativeness: The degree to which the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency and duration, and sampling methods.
- Completeness: The amount of data obtained from the measurement system.
- Comparability: The ability to compare data from the current project to data from other similar projects, regulatory requirements, and historical data.

Measurement quality objectives (MQOs) are performance or acceptance criteria that are established for each of these QA indicators. The specific MQOs to be used for this project are described below for the two primary monitoring components (i.e., hydrologic data and water quality data).

Measurement Quality Objectives – Hydrologic Data

Hydrologic monitoring will involve measurements of water level (for estimating discharge), as well as precipitation depth. Measurement quality objectives for these measurements are expressed in terms of bias, representativeness, completeness, and comparability. (Precision generally cannot be readily assessed due to the difficulty associated with obtaining repeat measurements from hydrologic monitoring equipment during continuously changing site conditions.) The associated MQOs for hydrologic monitoring are defined in the subsections below. If the measurement quality objectives are not met the data will be either flagged as an estimate (*J*) or rejected (*R*) (see *Data Verification and Validation*).

Bias

Bias will be assessed based on a comparison of monitoring equipment readings to an independently measured "true" value, determined by timing the flow of stormwater into a graduated container at the end of the primary measurement device. The MQO for discharge measurements will be a difference of no more than 25 percent between the instrument reading and an independently measured value for flows of between 10 and 100 percent of the primary measurement device capacity.

Representativeness

The representativeness of the hydrologic data will be ensured by the proper selection and installation of all associated monitoring equipment. Rainfall patterns, stormwater conveyance features, and surrounding land uses were also considered in the identification of monitoring locations and sampling frequencies to ensure that representative data will be obtained for this study. Finally, monitoring will be conducted over a sufficient length of time (3 years) to ensure that data are collected during representative climatic conditions for western Washington.

Completeness

Completeness will be assessed on the basis of the occurrence of gaps in the data record for all monitoring equipment. The associated MQO is less than 5 percent of the total data record missing due to equipment malfunction or other operational problems. Completeness will be ensured through routine maintenance of all monitoring equipment and the immediate (within 12 hours) implementation of corrective actions if problems arise.

Comparability

Although there is no numeric MQO for this data quality indicator, standard monitoring procedures, units of measurement, and reporting conventions will be applied in this study to meet the quality indicator of data comparability.

Measurement Quality Objectives – Water Quality Data

Quality assurance objectives for water quality data are expressed in terms of precision, bias, representativeness, completeness, and comparability. The associated MQOs are defined in the subsections below and summarized in Table 1 for those parameters of interest in this monitoring program. Note that the term "reporting limit" in this document refers to the practical quantification limit established by the laboratory, not the method detection limit.

Precision

In this study, two types of precision will be evaluated: total precision and analytical precision. The following sections describe the MQOs associated with each type of precision.

Total Precision

Total precision will be estimated using independent field duplicate samples and laboratory split samples. Overall project data quality will be based on total precision, but part of the process of determining data suitability will depend on meeting the analytical precision objectives (see below).

Table 1. Measurement quality objectives for water quality data.

Parameter	Laboratory Method and Field Blanks [a]	Control Standard Percent Recovery	Surrogate Percent Recovery	Matrix Spike Percent Recovery [b]	Laboratory and Field Duplicate *RPD* [c]	Laboratory and Field Duplicate *RSD* [d]
Total suspended solids	Not to exceed the RL	90–110%	NA	NA	≤25% or ±2 × RL	≤15%
Total phosphorus	Not to exceed the RL	90–110%	NA	75–125%	≤20% or ±2 × RL	≤10%
Ortho-phosphate	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Total Kjeldahl nitrogen	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Nitrate + nitrite nitrogen	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Polycyclic aromatic hydrocarbons	Not to exceed the RL	See Appendix D	See Appendix D	See Appendix D	≤20% or ±2 × RL (lab. dup. only)	NA
Hardness	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Copper, dissolved	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Copper, total	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Zinc, dissolved	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%
Zinc, total	Not to exceed the RL	90–110%	NA	75–125%	≤25% or ±2 × RL	≤15%

[a] If criterion is not met, associated blank concentration is defined as the new reporting limit and project sample data within five times this de facto reporting limit are flagged with a *J*.

[b] For inorganics, the Contract Laboratory Program (CLP) Functional Guidelines state that the spike recovery limits do not apply when the sample concentration exceeds the spike concentration by a factor of four or more (Ecology 2005).

[c] The relative percent difference must be less than or equal to the indicated percentage for values that are greater than five times the reporting limit. RPD must be and ±2 times the reporting limit for values that are less than or equal to five times the reporting limit.

[d] RSDp will only be calculated for values that exceed five times the RL.

mg/L = milligrams per liter.
NA = not applicable.
RL = reporting limit.
RPD = relative percent difference.
RSD = relative standard deviation.

For paired values that are both greater than five times the reporting limit, the pooled relative standard deviation (RSD_p) of laboratory and field duplicates will be ≤15 percent for total suspended solids (TSS) and ≤10 percent for nutrients, metals, polycyclic aromatic hydrocarbons (PAHs), and hardness. When one or both values are less than or equal to five times the reporting limit, they will not be included in the RSD_p calculation. RSD_p of duplicate field samples will be calculated using the following equation:

$$S_p = \sqrt{\frac{\sum (Ci_1 - Cj_2)^2}{2m}} \quad \text{and} \quad RSD_p = \frac{S_p}{\bar{x}} \times 100\%$$

where: S_p = pooled standard deviation

RSD_p = pooled relative standard deviation

Ci_1 and Cj_2 = concentration values

m = number of pairs.

as noted above:

For TSS, RSD_p ≤15 percent.
For all other parameters, RSD_p ≤10 percent.

Because there is no advantage in randomly selecting samples for replication, all available information and professional judgment will be used to select samples or measurements likely to yield results above five times the reporting limit (Ecology 2004). Consequently, duplicate samples will primarily be collected from the traditional metal roof because pollutant concentrations from the vegetated roof are expected to be low.

Analytical Precision

Analytical precision will be assessed by laboratory splits of samples, matrix spikes, and laboratory control samples (see below, under *Bias*). These will be assessed using relative percent difference (*RPD*).

$$RPD = \left(\frac{|C_1 - C_2|}{C_1 + C_2} \right) \times 200\%$$

where: RPD = relative percent difference

C_1 and C_2 = split sample concentration values.

For TSS, RPD ≤25 percent.
For all other parameters, RPD ≤20 percent.

If split sample concentrations are both within five times the reporting limit, the RPD goal for all parameters is less than two times the reporting limit. If either of the split samples is at or below the reporting limit, the MQO cannot be calculated. *RPD* values exceeding those described herein and in Table 1 will trigger an assessment as to whether there are any problems with the analytical laboratory methodology, which might warrant investigation and revision of the methodology.

Bias

Bias will be assessed based on the analyses of method blanks, field blanks, matrix spikes, and laboratory control samples (LCS). Specifically, field sample bias will be assessed with field blanks, while laboratory bias will be assessed with method blanks, matrix spikes, and laboratory control samples.

Field Sample Bias

Field blank results greater than the laboratory reporting limit (RL) will be flagged as a *de facto* detection limit (*U*), and associated project samples within five times the *de facto* reporting limit will be flagged as an estimate (*J*).

Laboratory Bias

The values for method blanks will not exceed the reporting limit. The percent recovery of matrix spikes will be between 75 and 125 percent for each parameter. The percent recovery of LCS will be within 90 and 110 percent for each parameter. Percent recovery for matrix spikes will be calculated using the following equation:

$$\%R = \frac{(S - U)}{C_{sa}} \times 100\%$$

where:	%R	=	percent recovery
	S	=	measured concentration in spike sample
	U	=	measured concentration in unspiked sample
	C_{sa}	=	actual concentration of spike added.

If the analyte is not detected in the unspiked sample, then a value of zero will be used in the equation.

Percent recovery for LCS will be calculated using the following equation:

$$\%R = \frac{M}{T} \times 100\%$$

where:	%R	=	percent recovery
	M	=	measured value
	T	=	true value.

Representativeness

The representativeness of the water quality data will be ensured by targeting representative storms for sampling based on the following criteria:

- Target storm depth: A **minimum of 0.25 inches** of precipitation over a 24-hour period.
- Antecedent conditions: A period of **at least 6 hours** preceding the event **with less than 0.04 inches** of precipitation.
- Minimum duration: Target storms must have a **duration of at least 1 hour**.
- End of storm: A continuous **6-hour period with less than 0.04 inches** of precipitation.

Completeness

Completeness will be calculated by dividing the number of valid values by the total number of values. Valid sample data consist of unflagged data and estimated data that have been assigned a *J* qualifier. If less than 95 percent of the samples submitted to the laboratory are judged to be valid, then additional samples will be collected until at least 95 percent are judged to be valid.

Comparability

Standard sampling procedures, analytical methods, units of measurement, and reporting limits will be applied in this study to meet the goal of data comparability. The results will be tabulated in standard spreadsheets to facilitate analysis and comparison with water quality threshold limits (i.e., Washington Administrative Code [WAC] 173-201A), where appropriate. Additionally, data will be submitted to Ecology in a format consistent with Ecology’s Environmental Information Management (EIM) System. This will ensure that the project data are in a format that is comparable to other data within the system.

Sampling Process Design

The experimental design for this project entails continuous monitoring of runoff volumes from two basketball courts and two roofs. This section describes in detail how the monitoring of each of these features will be designed.

Stormwater runoff from two separate basketball courts (one with impermeable pavement and one with a permeable pavement system) will be monitored at Grass Lawn Park. As shown in Figure 2, runoff from the impermeable pavement basketball court (6,300 square feet) will be routed to a catch basin via an 8-inch diameter drain pipe. To facilitate continuous monitoring of flow volumes from the impermeable pavement basketball court, a weir and pressure transducer will be installed in the outlet of this pipe (designated monitoring station IP in Figure 2). The impermeable court is raised above the surround pervious area and consequently run-on to the basketball court will not contribute to stormwater runoff monitored in the outlet catch basin.

Runoff from the permeable pavement basketball court (2,700 square feet) will be routed to the same catch basin where runoff from the impermeable court is routed (Figure 2). A weir and pressure transducer will also be installed in the outlet of this 8-inch pipe (designated monitoring station PP in Figure 2) to allow continuous monitoring of flow volumes from the permeable pavement basketball court. To prevent run-on to this basketball court from adjacent areas a French drain system will be installed on the upslope edge of this basketball court. Water entering the French drain will be routed to the municipal storm sewer. The pressure transducer cabling from both monitoring stations IP and PP will be routed to a mechanical room in the park pavilion (see Figure 2) where a data logger will be installed and programmed to store water level data at 5-minute intervals. These data will also be processed within the data logger to calculate flow rates at each station. Finally, a telemetry system will be installed in association with the data logger to provide remote access to these data.

Continuous monitoring of runoff volumes will also be performed in association with a traditional metal roof (on the pavilion) and a vegetated roof (on the new maintenance building). As shown in Figure 2, runoff from the new pavilion's traditional metal roof (1,640 square feet) will be routed via an 8-inch drain pipe to a swale along the north side of the pavilion structure. To allow continuous monitoring of flow volumes from the traditional roof, a weir and pressure transducer will be installed in the outlet of this pipe (designated monitoring station MR in Figure 2). The pressure transducer cabling from this monitoring station will be routed to a mechanical room in the pavilion and interfaced with the data logger described above in conjunction with monitoring stations IP and PP.

As shown in Figure 2, runoff from the maintenance building's vegetated roof (1,330 square feet) will be routed to a catch basin via an 8-inch drain pipe. A weir and pressure transducer will be installed at the outlet of the pipe (designated monitoring station VR in Figure 2) to allow continuous monitoring of flow volumes from the vegetated roof during higher flows. Because runoff volumes from the vegetated roof are expected to be relatively low at times, a rain gauge will also be installed below the weir to improve the monitoring accuracy of these lower volumes.

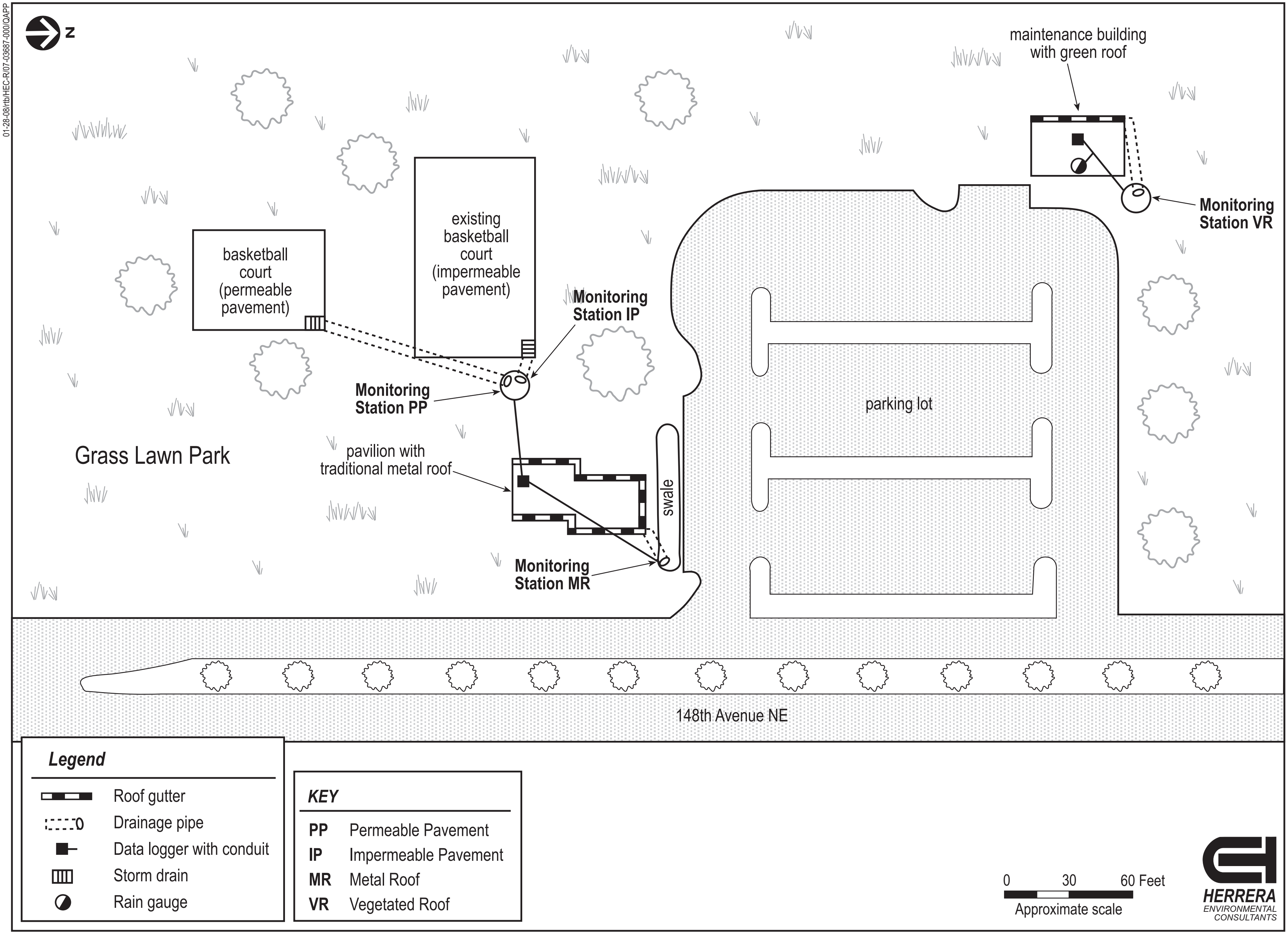

Figure 2. Site schematic for the Grass Lawn Park low impact development monitoring study.

The rain gauge and pressure transducer cables will be routed to a data logger within the maintenance building. A second rain gauge will be installed on the roof of the maintenance building to provide continuous monitoring of precipitation. This rain gauge will also be connected to the data logger within the maintenance building. The data logger will be programmed to record readings from the pressure transducer and the two rain gauges at 5-minute intervals. Finally, a telemetry system will be installed in association with the data logger to allow remote access to the data.

Area-weighted flow data from the permeable pavement basketball court will be compared with area-weighted flow data from the impermeable pavement court to assess the storm volume and flow rate reduction potential of the permeable pavement court. Additionally, runoff volumes will be compared with precipitation volumes (from the rain gauge on the nearby vegetated roof) across the surface of each court to determine rainfall–runoff relationships for both the permeable and impermeable surfaces. To assess the performance of the vegetated roof, area-weighted flow data from the vegetated roof will be compared with area-weighted flow data from the traditional metal roof. Precipitation data from the rain gauge on the vegetated roof will also be used in conjunction with flow data to develop rainfall–runoff relationships for both roofs.

Finally, grab samples will be collected during six discrete storm events in each of the three monitoring years to assess the quality of runoff from the traditional and vegetated roofs. Because runoff from the LID features is expected to be low, only storms greater than 0.25 inches in 24 hours will be targeted for sampling. Field personnel will target the rising limb (i.e., the beginning) and peak of the target storms to increase the likelihood of collecting concentrations of pollutants above the laboratory reporting limit. Grab samples will be collected from the vegetated roof and traditional metal roof monitoring stations using standard sample collection techniques (see *Sampling Procedures,* below), and shipped that day for next-day delivery (if possible) to the Manchester Environmental Laboratory (Manchester Laboratory) in Port Orchard, Washington. Samples collected from the both roofs will be analyzed for the following parameters:

- Total suspended solids (TSS)
- Hardness
- Total and dissolved zinc
- Total and dissolved copper
- Total phosphorus (TP)
- Ortho-phosphate phosphorus
- Total Kjeldahl nitrogen (TKN)
- Nitrate + nitrite nitrogen
- Polycyclic aromatic hydrocarbons (PAHs).

Water quality data from the vegetated roof and traditional metal roof will be compared to assess their relative pollutant export (or removal) characteristics (see *Data Analysis Procedures,* below).

Sampling Procedures

As described above, this study is designed to assess the stormwater treatment benefit of two different LID features, a vegetated roof and a permeable pavement basketball court. The specific procedures that will be used for continuous hydrologic monitoring and water quality field sample collection are described in the following subsections.

Continuous Hydrologic Monitoring

Pipes conveying runoff from each of the monitored basketball courts will terminate in the monitoring catch basin located east of the impermeable pavement court (Figure 2). Thel-Mar weir inserts (Appendix C) will be installed at the end of each pipe (designated as monitoring stations PP and IP in Figure 2) to serve as primary measurement devices. Holes will be drilled through the face of each weir insert, and reinforced with 3/8-inch internal diameter (ID) polyethylene tubing that will be connected to the holes. The other end of the tubing will be connected to 4-inch (ID) polyvinyl chloride (PVC) stilling wells, which will be affixed to the interior wall of the monitoring catch basin. Druck 1830 (0 – 0.25 pounds per square inch [psi]) pressure transducers (also called a CS420 pressure transducer; see Appendix C) will be installed in the stilling wells to measure water level. If the average storm flow from the permeable pavement court is near the minimum recommended flow rate (0.00009 cubic feet per second [cfs]) for the Thel-Mar weir, then a tipping bucket rain gauge (Campbell Scientific CS700 Appendix C) may be installed below the weir to monitor very low flows. The wires from the pressure transducers and rain gauge (if required) will be routed through 4-inch (ID) conduit to a CR1000 Campbell Scientific data logger (Appendix C) located in the mechanical room of the pavilion (Figure 2). The data logger will be connected to AC power and a dedicated phone line so that data can be remotely downloaded.

As shown in Figure 2, runoff from the pavilion's traditional metal roof will be routed via an 8-inch drain pipe to a swale along the north side of the pavilion. A Thel-Mar weir will be installed at the end of the pipe (designated as monitoring station MR in Figure 2). A Druck 1830 pressure transducer will also be installed in association with the weir using the procedure identified above for monitoring stations PP and IP. This pressure transducer will also be connected to the Campbell Scientific CR1000 data logger in the pavilion.

The vegetated roof on the maintenance building will be monitored from a monitoring catch basin located to the east of the building (Figure 2). Runoff from the roof will be routed to the monitoring catch basin via an 8-inch drain pipe. A Thel-Mar weir will be installed in the outlet of this pipe (designated as monitoring station VR in Figure 2) and equipped with a stilling well and Druck 1830 pressure transducer, as described above. Because flow from the vegetated roof is expected to be low, a tipping bucket rain gauge (Campbell Scientific CS700) will be installed below the Thel-Mar weir to characterize very low flow conditions (i.e., below 0.00009 cfs, the lower design limit of the weir). Communication wires from the rain gauge and pressure transducer will be routed through 4-inch (ID) conduit to a Campbell Scientific CR800 data logger (Appendix C) located in the maintenance building. Additionally, a tipping bucket rain gauge (Campbell Scientific CS700) will be installed on the roof of the maintenance building to monitor precipitation; this rain gauge will also be connected to the data logger in the maintenance building. The data logger will have AC power and will be connected to a dedicated phone line for remote communication purposes.

Each data logger will be programmed to continuously record water level measurements from the pressure transducers and tip count from the rain gauges at each monitoring station using a 5-minute logging interval. The data loggers will be programmed with standard hydraulic equations for converting the water level measurements behind the weirs to estimates of discharge. These data will be remotely downloaded on a weekly basis and after each sampled storm event.

One week after installation, field personnel will visit the site to confirm that the monitoring equipment was installed correctly and is functioning properly. After this initial check, Herrera's field personnel will perform monthly site visits to visually inspect all system components and perform routine calibrations as necessary. Any operational problems identified during these site visits will be addressed immediately. Field personnel will record detailed notes to describe any equipment maintenance or repairs that are required during these site visits. Standardized field forms will be used to document maintenance, calibration, and troubleshooting activities. (A sample form is included in Appendix B).

Water Quality Sample Collection

Water quality samples will be collected from the vegetated roof and the traditional metal roof during six separate storm events in each of the three monitoring years. Initially storms events that occur during the wet season will be targeted. If it is shown that the vegetated roof produces measurable flows during dry season storm events then ~20 percent of the targeted storms (1 of 6) will be dry season storms. One sample will be collected from each site for a total of two samples per event. A field duplicate and field blank will be collected during every fourth event for a total of four QA field samples at the end of the study (with the goal of collecting enough QA samples to constitute 10 percent of the total number of project samples).

Precipitation forecasts from the Center for Ocean Land–Atmosphere Studies (http://wxmaps.org/pix/meteograms.html) will be reviewed on a weekly basis to determine if specific storm events should be targeted for sampling. Immediately prior to sampling, incoming storms will be tracked using Doppler radar images for the region, accessed via the King 5 weather website (http://www.king5.com/weather/doppler/?seattle). To the extent possible, the timing of sample collection for each monitoring station will be targeted to capture the rising limb of the storm hydrograph.

All samples will be collected using precleaned bottles supplied by the laboratory. Samples will be collected by holding the bottle under the terminus of the pipes draining each of the monitored roofs until the bottle is full. Field filtering for ortho-phosphate phosphorus and dissolved metals analysis will occur within 15 minutes of sample collection, following the procedures outlined in the *Quality Control*/*Sample Handling* section that follows. Water quality sampling for metals will be conducted using a modified version of the "clean hands" and "dirty hands" protocol developed by the U.S. Environmental Protection Agency (U.S. EPA 1996) for the low-level detection of metals. The modified version of this protocol will allow sampling to be performed by one field technician as opposed to two, as described under *Quality Control/Sample Handling*.

Following collection, each sample bottle will be capped and placed in a cooler with ice and kept below 6°C until shipment to the laboratory. As soon as possible after sample collection, samples will be placed in Ziploc® bags, packed on ice, and then packaged and shipped via "next-day" Fed-Ex delivery. A completed chain-of-custody record will be submitted with each batch of samples. Each collected sample will then be analyzed for total suspended solids, total phosphorus, ortho-phosphate phosphorus, total Kjeldahl nitrogen, nitrate + nitrite nitrogen, total hardness, polycyclic aromatic hydrocarbons, total copper, dissolved copper, total zinc, and dissolved zinc.

Documentation of Field Activities

Field personnel will record all field activities in a waterproof field notebook during the collection of water quality samples and maintenance of hydrologic equipment. Documentation of field sampling activities will include the monitoring station ID, location, sampling time, sampling date, and sample collector's name/signature. Any relevant observations regarding site conditions at the time of sampling will also be recorded including; water appearance, weather, biological activity, unusual odors, specific sample information, and days since the last significant rainfall. Standardized field forms will be used to document equipment maintenance, calibration, and troubleshooting activities. (See the sample form in Appendix B). Once field personnel have returned to the office, all field notes and standardized forms will be reviewed by the Data Quality Assurance Officer for completeness and conformity with the procedures identified in this QAPP.

Measurement Procedures

As noted previously, samples collected for this project will be analyzed for total suspended solids, total phosphorus, ortho-phosphate phosphorus, total Kjeldahl nitrogen, nitrate + nitrite nitrogen, total hardness, PAHs, total copper, dissolved copper, total zinc, and dissolved zinc. Laboratory analytical procedures for these analytes will follow methods approved by the U.S. EPA (APHA et al. 1992; U.S. EPA 1983, 1984). These methods provide reporting limits that are low enough to assess water quality at low pollutant concentrations, and below the state and federal regulatory criteria or guidelines, which will allow comparison of the analytical results with these regulatory levels. The preservation methods, analytical methods, reporting limits, and sample holding times for these parameters are listed in Table 2.

The laboratory identified for this project (Ecology's Manchester Laboratory) is certified by Ecology and participates in audits and interlaboratory studies by Ecology and the U.S. EPA. These performance and system audits have verified the adequacy of the laboratory's standard operating procedures, which include preventive maintenance, data reduction, and quality assurance/quality control (QA/QC) procedures.

The laboratory will report the analytical results within 30 days of receipt of the samples. The laboratory will provide all sample and quality control data in standardized laboratory reports suitable for evaluating the project data. The laboratory reports will include all raw data, including but not limited to:

- All raw values, including those below the reporting limit and between the method detection limit and the laboratory reporting limit
- The laboratory method detection limits and reporting limits for all analytes for each batch
- All field duplicate and laboratory split sample results.

Data will be submitted in hardcopy and compiled in electronic format in one of the following: a Microsoft Excel (version 97 or later) spreadsheet, Microsoft Access database table (version 97 or later), or a dBase IV database table. The reports will also include a case narrative summarizing any problems encountered in the analyses.

Table 2. Methods and reporting limits for water quality analyses.

Parameter	Analytical Method	Method Number [a]	Field Sample Container	Pre-Filtration Holding Time [b]	Total Holding Time [b]	Field Preservation	Laboratory Preservation	Reporting Limit/ Resolution	Units
Total suspended solids	Gravimetric	I-3765-85	1 L HDPE bottle **(A)**	7 days	7 days	Maintain ≤ 6°C	Maintain 4°C	2.0	mg/L
Total phosphorus	Digestion/ Colorimetric	EPA 365.1	250 mL HDPE **(B)**	NA	28 days	Maintain ≤ 6°C	Maintain 4°C, H_2SO_4 to pH < 2	0.02	mg/L
Ortho-phosphate phosphorus	Colorimetric	EPA 365.2	250 mL HDPE **(C)**	15 minutes	48 hours	Filter (0.45-micron syringe), Maintain ≤ 6°C	Maintain 4°C, H_2SO_4 to pH < 2	0.05	mg/L
Total Kjeldahl nitrogen	Digestion/ Colorimetric	EPA 351.2	250 mL HDPE **(B)**	NA	28 days	Maintain ≤ 6°C	Maintain 4°C, H_2SO_4 to pH < 2	0.1	mg/L
Nitrate + nitrite nitrogen	Digestion/ Colorimetric	EPA 353.2	250 mL HDPE **(B)**	48 hours	28 days	Maintain ≤ 6°C	Maintain 4°C, H_2SO_4 to pH < 2	0.01	mg/L
Polycyclic aromatic hydrocarbons	GC/MS	EPA 8270D	500 mL amber glass bottle **(D)**	NA	7 days	Maintain ≤ 6°C	Maintain 4°C	1.0	µg /L
Hardness as $CaCO_3$	ICP-AES	SM 2340B	250 mL HDPE, Teflon-lined lid **(E)**	NA	6 months	Maintain ≤ 6°C	Maintain 4°C, HNO_3 to pH < 2	0.25	mg/L
Copper, dissolved	ICP-MS	EPA 200.8	250 mL HDPE, Teflon-lined lid **(F)**	15 minute	6 months	Filter (0.45-micron syringe), Maintain ≤ 6°C	Maintain 4°C, HNO_3 to pH < 2 after filtration	1.3	µg /L
Copper, total			250 mL HDPE, Teflon-lined lid **(E)**	NA		Maintain ≤ 6°C	Maintain 4°C, HNO_3 to pH < 2		
Zinc, dissolved	ICP-MS	EPA 200.8	250 mL HDPE, Teflon-lined lid **(F)**	15 minute	6 months	Filter (0.45-micron syringe), Maintain ≤ 6°C	Maintain 4°C, HNO_3 to pH < 2 after filtration	2.5	µg /L
Zinc, total			250 mL HDPE, Teflon-lined lid **(E)**	NA		Maintain ≤ 6°C	Maintain 4°C, HNO_3 to pH < 2		

Note: Some field sample containers will be used to collect water for multiple constituents. Field sample containers that share the same **bold** letter in parenthesis are the same bottle.

[a] SM method numbers are from APHA et al. (1998); EPA method numbers are from U.S. EPA (1983, 1984); total suspended solids method is from U.S. Geological Survey *Techniques of Water Resources Investigations* (Fishman and Friedman 1989); Method 8270D is from http://www.epa.gov/epaoswer/hazwaste/test/pdfs/8270d.pdf.

[b] Holding time specified in U.S. EPA guidance (U.S. EPA 1983, 1984) or referenced in APHA et al. (1998) for equivalent method.

°C = degrees Celsius.
HDPE = high-density polyethylene.
ICP = inductively coupled plasma – atomic emission spectroscopy.
ICP-MS = inductively coupled plasma/mass spectrometry.
GC/MS = gas chromatography/mass spectroscopy.
mg/L = milligrams per liter.
NA = not applicable.

Quality Control

The quality control procedures described below will be implemented to ensure that the measurement quality objectives for this study are met for both field and laboratory activities. The overall objective of these procedures is to ensure that data collected for this project are of a known and acceptable quality.

Field Quality Control Procedures

Quality control procedures to be implemented for field activities are described in the following subsections. The frequency and type of quality control samples to be collected in the field are also summarized in Table 3.

Table 3. Anticipated number of samples and associated quality assurance requirements for each study parameter.

Parameter	Samples per Station [a]	Number of Stations	Total Number of Samples	Laboratory Method Blanks [b]	Field Blanks	Laboratory Control Standard [b]	Matrix Spike [b]	Field Duplicates	Lab Duplicates [b]
Total suspended solids	18	2	36	1/batch	NA	1/batch	NA	4	1/batch
Total phosphorus	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch
Ortho-phosphate phosphorus	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch
Total Kjeldahl nitrogen	18	2	36	1/batch	NA	1/batch	1/batch	4	1/batch
Nitrate + nitrite nitrogen	18	2	36	1/batch	NA	1/batch	1/batch	4	1/batch
Polycyclic aromatic hydrocarbons	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch
Hardness	18	2	36	1/batch	NA	1/batch	1/batch	4	1/batch
Copper, dissolved	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch
Copper, total	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch
Zinc, dissolved	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch
Zinc, total	18	2	36	1/batch	4	1/batch	1/batch	4	1/batch

[a] Six samples will be collected per year during the 3-year duration of the study, for a total of 18 samples per monitoring station.
[b] Laboratory QA samples will be analyzed with each batch of samples submitted to the laboratory for analysis. A laboratory batch will consist of no more than 20 samples.
NA: not applicable.

Instrument Maintenance and Calibration

The calibration of all monitoring equipment will be checked on a regular basis. The specific calibration procedures and frequency that will be applied to the discharge and precipitation monitoring equipment are described in the following subsections.

Instrument/Equipment Testing, Inspection, and Maintenance

All monitoring equipment will be tested prior to installation to ensure it is functioning correctly. One week after installation, field personnel will visit the site to confirm that the monitoring equipment was installed correctly and is functioning properly.

After this initial check, site visits will be performed at least monthly to perform routine maintenance on the equipment. Maintenance activities will include:

- Check power connections and phone lines
- Visually inspect all system components for wear or damage
- Remove any debris that may have accumulated on monitoring equipment
- Replace desiccant in data logger boxes.

Field personnel will take detailed notes to describe any equipment maintenance or repairs that are required during these site visits. Standardized field forms will be used to document maintenance, calibration, and troubleshooting activities (a sample form is included in Appendix B).

Flow Monitoring Equipment Calibration and Frequency

During each monthly site visit, field personnel will insert an inflatable bladder into the pipe behind the weir and inflate the device until a seal forms between the bladder and the interior wall of the pipe. The pipe will then be filled with water until it flows through the v-notch. Once the flow has decreased to zero and the water level is equal with the bottom of the v-notch, the pressure transducer will be calibrated to zero. The offset between the pressure transducer elevation and the v-notch elevation will be recorded during each calibration event. Offset values will be tracked over time by means of control charts to detect potential instrument drift and other operational problems. This information will be used to assess the MQOs that are identified in the *Quality Objectives* section above. If the data do not meet the specific MQOs defined for each indicator, corrective actions will be implemented.

Precipitation Monitoring Equipment Calibration and Frequency

Annual site visits will be conducted to check the calibration of the rain gauges. During each site visit, field personnel will determine the exact volume of water required to initiate one tip of the rain gauge bucket by adding incremental drops of water with a pipette. The measurements will be repeated ten times and then averaged. The resultant value will be compared to the manufacturer's specifications for the volume required to initiate one bucket tip. The difference between these values will be used to assess the MQOs identified in the *Quality Objectives* section above. If the data do not meet the specific MQOs defined for each indicator, corrective actions will be implemented.

Field Blanks

Field blanks will be collected to verify that sample contamination is not occurring during the sample collection and shipping process. To collect the field blank sample, sample bottles will be filled with reagent grade water at each monitoring station and delivered along with the project samples to the laboratory. One field blank will be collected during every fourth storm event to be sampled in connection with this QAPP (with the goal of collecting enough QA samples to constitute 10 percent of the total number of project samples).

Field Duplicates

Field duplicates will be collected by filling a second sample bottle immediately after the collection of the regular sample. One field duplicate will be collected during every fourth storm event to be sampled in connection with this QAPP (with the goal of collecting enough QA samples to constitute 10 percent of the total number of project samples). Field duplicates will be collected either from the monitoring station for the traditional metal roof, or the station for the impermeable pavement basketball court. This will increase the likelihood that the sample will have a concentration above the reporting limit. All field duplicate samples will be submitted to the laboratory and labeled as separate (blind) samples. The resultant data from these samples will be used to assess the observed variation in the analytical results that is attributable to environmental (natural), sampling, and analytical variability. Relative percent difference values (see the formula in the *Quality Objectives* section above) will be calculated for each set of field duplicates from the laboratory results.

Sample Handling

Metals Sample Collection

A modified version of the U.S. EPA's "clean hands" and "dirty hands" protocol for low-level detection of metals will be used during sample collection. The modified version of the protocol will allow sampling to be performed by one field technician as opposed to two. Accordingly, the laboratory will preclean laboratory bottles for metals, as required for the analytical method. The laboratory will then place the metals bottles into two separate Ziploc® bags for transport to the site. Prior to sample collection, the field technician will don a new set of gloves (i.e., clean, nontalc gloves made of polyethylene, latex, or vinyl) for each sequence of clean or dirty hands operations that is required for proper implementation of the protocol. The sequence of clean and dirty hands operations to be used during sampling is described in detail as follows:

- Dirty Hands (two sets of new gloves):
  - Open the cooler with sample bottles
  - Remove double-bagged sample bottle from cooler
  - Unseal outer bag.
- Clean Hands (remove outer set of gloves):
  - Unseal inner bag containing sample bottle
  - Remove bottle and unscrew cap

- ☐ Rinse bottle three times in water to be sampled (if sample contains no preservative)
- ☐ Fill sample bottle
- ☐ Return sample bottle to inner bag
- ☐ Reseal inner bag
- ☐ Reseal outer bag
- ☐ Return double-bagged sample to cooler.

Sample Transport

Once all samples have been collected, they will be placed in plastic bags with ice and packaged for overnight delivery to the Manchester Laboratory. The box will be addressed as follows:

Attn: Bethany Plewe
Grass Lawn LID Samples
Manchester Environmental Laboratory
7411 Beach Drive East
Port Orchard, WA 98366

Field personnel will also label the shipping container with the following:

- Nontoxic
- Breakable
- Water Samples—Refrigerate Immediately Upon Receipt.

Laboratory Sample Handling

To minimize exposure of the samples to human, atmospheric, and other potential sources of contamination, laboratory staff will process the samples using "clean" techniques pursuant to protocols developed by the U.S. EPA (1996) for the low-level detection of metals.

Sample Identification and Labeling

A water quality sampling station naming convention will be implemented to reduce site identification errors. Each water quality sampling station will be named using the following conventions:

- The pavilion roof (metal) will be labeled as monitoring station MR.
- The maintenance building roof (vegetated roof) will be labeled as monitoring station VR.

All sample containers will be labeled with the following information using indelible ink and labeling tape:

- Monitoring station name
- Date of sample collection (year/month/day: yyyy/mm/dd)
- Time of sample collection (international format [24 hour])
- Initials of field personnel.

QA samples (field duplicates and blanks) will be labeled as QA1, QA2, etc. for delivery to the laboratory, but field personnel will maintain a cross-check list of which stations and sample types the QA samples represent. When results are returned from the laboratory, Herrera will correlate the full label information with the analytical results from the laboratory and populate database fields for each QA sample and type.

Waterproof labels will be placed on dry sample container lids by self-adhesion or with tape. Waterproof labeling tape may be employed. Any written marks will be made with waterproof ink.

Sample Containers and Preservation

During each water quality sample collection round, six sample bottles will be filled at each monitoring station. A 1-liter high-density polyethylene (HDPE) bottle will be filled for suspended solids analysis, a 250-milliliter HDPE bottle will be filled for ortho-phosphate phosphorus analysis, a 250-milliliter HDPE bottle will be filled for total phosphorus and nitrogen species analysis, a 250-milliliter HDPE bottle will be filled for total metals and hardness analyses, a 250-milliliter HDPE bottle will be fill for dissolved metals analysis, and a 500-milliliter amber glass bottle will be filled for PAH analysis. Sample containers and preservation techniques will follow guidelines in U.S. EPA (2007).

Chain-of-Custody Record

A chain-of-custody record will be maintained for each sample batch, listing the sampling date and time, sample identification numbers, analytical parameters and methods, persons relinquishing and receiving custody, dates and times of custody transfer, and temperature of sample upon delivery. The chain-of-custody form will be included with the samples when they are shipped to the laboratory.

Laboratory Quality Control Procedures

Quality control procedures to be implemented in the laboratory are described in the following subsections. The frequency and type of quality control samples to be analyzed by the laboratory are summarized in Table 3.

Method Blanks

Method blanks consisting of deionized and microfiltered pure water will be analyzed with every laboratory sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of method blanks anticipated for this study is listed in Table 3 by parameter. Blank values will be presented in each laboratory report.

Control Standards

Control standards for each parameter will be analyzed by the laboratory with every sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of control standards anticipated for this study is listed in Table 3 by parameter. Raw values and percent recovery (see the formula in the *Quality Objectives* section) for the control standards will be presented in each laboratory report.

Matrix Spikes

For applicable parameters (all parameters except total suspended solids, as listed in Table 1), matrix spikes will be analyzed by the laboratory with every sample batch. A laboratory sample batch will consist of no more than 20 samples and may include samples from other projects. The total number of matrix spikes anticipated for this study is listed in Table 3 by parameter. Raw values and percent recovery (see the formula in the *Quality Objectives* section) for the matrix spikes will be presented in each laboratory report.

Laboratory Duplicates (Split Project Samples)

Laboratory split-sample duplicates for each parameter will be analyzed for specifically labeled QA samples submitted with every sample batch. These will represent no less than 10 percent of the submitted project samples. The total number of laboratory duplicates anticipated for this study is listed in Table 3 by parameter. Raw values and relative percent difference (see the formula in the *Quality Objectives* section) of the duplicate results will be presented in each laboratory report.

Laboratory Duplicates (Matrix Spike Duplicates)

Matrix spike duplicates (MSDs) will be run at least twice per water-year for copper and zinc, in conjunction with matrix spike analyses from samples submitted for this project. Additionally, matrix spike duplicates will be run with every batch of PAH samples analyzed.

Data Management Procedures

Data from the two data loggers at the study site will be remotely uploaded on at least a weekly basis. These data will be immediately checked for evidence of an equipment malfunction or other operational problem. The hydrologic data from each monitoring station will be imported directly into a database (using Isco Flowlink software [Isco 2007]) for subsequent analysis and archiving purposes. The database will be used to produce event-based hydrologic summary statistics for each station (e.g., station runoff volume, storm precipitation total, storm duration). If gaps in flow data need to be interpolated, data will be stored and presented in a manner that makes it clear what data are from measurement, and what have been interpolated. All monitoring and quality assurance data associated with this study will be managed in a format that will be available to secondary users for 10 years after the completion of the monitoring program (in compliance with the 10-year rule) (Ecology 2006).

The Manchester Laboratory will report the analytical results within 30 days of receipt of the samples. The laboratory will provide sample and quality control data in standardized reports that are suitable for evaluating the project data. These reports will include all raw data, including raw quality assurance data, and all quality control results associated with the data. The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Manchester Laboratory will provide analytical and quality assurance results in both electronic and hardcopy form. These data will be submitted to the City as appendices to the final report and in electronic and hardcopy form as an appendix to the semiannual data report summaries.

Analytical data for the project will ultimately be stored in a database (Microsoft Access) that will be developed for the project with related event-based hydrologic statistics (e.g., precipitation total, station flow volume, etc.) for each sampled storm. The Herrera Data Quality Assurance Officer will perform an independent review of the database to ensure that all sample values are entered without error. This review will consist of checking that all laboratory data are entered into the database correctly. An assessment will also be made for data completeness. Additional sampling may be required if an adequate number of samples meeting QA/QC objectives have not been collected. At the end of the 3-year monitoring effort and subsequent to all data entry and quality assurance procedures, the data will be made available to Ecology for use in their EIM system. All data related to the project will be retained for a period of 10 years.

Audits and Reports

Routine audits will be conducted to ensure that this QAPP is being implemented correctly and the quality of the data is acceptable. In the event that QA issues are identified during an audit, corrective actions will be implemented as necessary. Monitoring data obtained through implementation of this QAPP will also be summarized in semiannual data reports. The sections below describe in detail the steps to be carried out in connection with each of these activities.

Deficiencies, Nonconformances, and Corrective Action

Deficiencies are defined as unauthorized deviations from those procedures documented in the QAPP. Nonconformances are deficiencies that severely affect the data quality and render them unacceptable or indeterminate. Deficiencies related to field and laboratory measurement systems include, but are not limited to, instrument malfunctions, blank contamination, and quality control sample failures.

Routine audits will be performed to detect potential deficiencies in the hydrologic and water quality data collected for this project. Audits for hydrologic data will occur on a weekly to biweekly basis, when data are remotely downloaded from the monitoring stations. In connection with these audits, the newly downloaded data will be compared with previously downloaded and audited data to identify potential quality assurance issues. This audit will specifically include an examination of the data record for gaps, anomalies, or inconsistencies among the discharge, water level, and/or precipitation data from the various monitoring stations. Any data generated from calibration checks that were performed at a particular monitoring station will also be entered into control charts and reviewed to detect potential instrument drift or other operational problems. If quality assurance issues are identified on the basis of these audits, a site visit will be performed immediately to troubleshoot the problem and to implement corrective actions if possible. Any quality assurance issues that are detected through these audits will be documented in the electronic data record and in separate tracking forms (Appendix B).

Audits performed for water quality data will occur within 7 business days of receiving results from the laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Results from these audits will be documented in quality assurance worksheets that will be prepared for each batch of samples. In the event that a potential quality assurance issue is identified through these audits, the Data Quality Assurance Officer will review the data to determine if any response actions are required. Response actions in this case might include the collection of additional samples or the reanalysis of existing samples. If it is found that the laboratory is unable to consistently meet the measurement quality objective the laboratory will be contacted and corrective measures will be agreed upon.

Deficiencies detected through routine audits will be documented in accordance with the procedures identified above. The Herrera Project Manager, in consultation with the Data Quality Assurance Officer, will determine if the deficiency constitutes a nonconformance. If it is determined that a nonconformance exists, the Data Quality Assurance Officer will decide the disposition of the nonconforming data and any necessary corrective action(s). Corrective actions may include the qualification of the data as estimated (*J*) or rejected (*R*) values. All deficiencies, nonconformances, and corrective actions will be documented in semiannual data reports for the project.

Reporting Procedures

In conjunction with this project, Herrera will prepare semiannual data reports to summarize the collected data and related analytical results. In accordance with the schedule presented in the *Organization and Schedule* section, each semiannual data report will present the monitoring data collected during the previous 6 months. These data reports will include the following information:

- Overview of the project goals and objectives
- Description of the data collection procedures
- Hydrologic monitoring results for each station
- Water quality monitoring results for the vegetated and traditional metal roofs
- Graphical and/or tabular representations of the data, as necessary.

Appendices to the report will also include tabular compilations of raw monitoring data, field data sheets, laboratory analytical reports, chain-of-custody documentation, and the quality assurance memoranda (as described in more detail in the *Data Quality [Usability] Assessment* section). Each semiannual data report will be submitted to the City for review, comment, and approval.

Results from the monitoring program will also be summarized in a final data report, in accordance with the schedule provided in the *Organization and Schedule* section. The final data report will include the following sections:

- Executive summary
- Introduction and background
- Site description
- Monitoring methods
- Data validation results
- Results from water quality sampling

- Results from flow monitoring
- Graphical and tabular summaries of the collected data
- Results from comparisons in hydrology and water quality between the monitoring sites
- Conclusions
- Appendices: Quality assurance memorandum, raw data tables, field data sheets, chain-of-custody documentation.

A draft copy of the final data report will be submitted to the City for review. The report will then be revised and submitted to Ecology for final approval. All data will also be compiled in a format that is compatible with Ecology's EIM system (see *Data Management Procedures* above).

Data Verification and Validation

Data verification and validation will be performed on both the hydrologic and water quality data collected through the duration of this project. The specific procedures to be used to verify and validate each type of data are described in the following sections.

Verification and Validation Methods for Hydrologic Data

The verification and validation process for hydrologic data will involve the following steps:

- Precipitation data will be reviewed to identify any significant gaps. If possible, these gaps will be filled using data obtained from a nearby rain gauge.

- The available discharge and water level data from each monitoring station will be verified based on comparisons of the associated hydrographs to the hyetographs for individual storm events. Gross anomalies (e.g., data spikes), gaps, or inconsistencies identified through this review will be investigated to determine if there are quality assurance issues associated with the data that may limit their usability.

- If minor quality assurance issues are identified in any portion of the discharge record or in the water level data from a particular station and storm event, the data from that station and event will be considered as an estimate and assigned a (*J*) qualifier. If major quality assurance issues are identified in any portion of the data from a particular station and/or storm event, the data from that station and event will be rejected and assigned an (*R*) qualifier. Estimated values will be used for evaluation purposes, while rejected values will not.

Verification and Validation Methods for Water Quality Data

Data will be reviewed and audited within 7 business days of receiving the results from the field or laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Specific quality control elements for the data (see Table 1) will also be examined to determine if the MQOs for the project have been met. Results from these data validation reviews will be summarized in quality assurance worksheets that are prepared for each sample batch (see Appendix B). Values associated with minor quality control problems will be considered estimates and assigned *J* qualifiers. Values associated with major quality control problems will be rejected and qualified as *R*. Estimated values may be used for evaluation purposes, while rejected values will not be used. Data validation procedures are described below for the following quality control elements:

- Completeness
- Methodology
- Holding times
- Method and field blanks
- Reporting limits
- Duplicates
- Matrix spikes and matrix spike duplicates
- Control standards.

Completeness

Completeness will be assessed by comparing valid sample data with this quality assurance project plan and the chain-of-custody records. Completeness will be calculated by dividing the number of valid values by the total number of values. If less than 95 percent of the samples submitted to the laboratory are judged to be valid, then more samples will be collected until at least 95 percent are judged to be valid. If less than 95 percent of the collected flow data are complete, additional monitoring will be implemented until 95 percent of the flow record has been collected.

Methodology

Methodologies for analytical procedures will follow U.S. EPA-approved methods (APHA et al. 1992; U.S. EPA 1983, 1984) specified in Table 2. Field procedures will follow the methodologies described in this quality assurance project plan. Any deviations from these methodologies must be approved by the City of Redmond and documented in an addendum to this QAPP. The database will include a field for identifying the analytical method. Deviations that are deemed unacceptable will result in rejected values (*R*) and will be corrected for future analyses.

Holding Times

Holding times for each analytical parameter in this study are summarized in Table 2. Holding time compliance will be assessed by comparing the sample collection dates and times to the filtration and analytical dates and times.

Pre-Filtration Holding Time

Ortho-phosphate phosphorus and dissolved metals will be filtered in the field within 15 minutes of sampling. If filtering occurs between 15 minutes and 30 minutes, the sample will be labeled with a *J*. If field filtering occurs after 30 minutes, the sample will be rejected and labeled with an *R*. Nitrate + nitrite nitrogen must be filtered and analyzed within 48 hours. If filtration occurs between 48 and 72 hours, the sample will be flagged as an estimate (*J*). If filtration occurs after 72 hours, the sample will be rejected and flagged with an *R*.

Total Holding Time

For analytes with total holding times in excess of 7 days:

- Data from samples that exceed the specified maximum total holding times by less than 48 hours will be considered estimates (*J*). Data from samples that exceed the maximum post-filtration holding times by more than 48 hours will be rejected (*R*) values.

For analytes with total holding times equal to or less than 7 days:

- Data from samples that exceed the specified maximum total holding times by less than 24 hours will be considered estimates (*J*). Data from samples that exceed the maximum post-filtration holding times by more than 24 hours will be rejected (*R*) values.

Method and Field Blanks

Method blank values will be compared to the MQOs identified for this project (see Table 1). If an analyte is detected in a method blank at or below the reporting limit, no action will be taken. If blank concentrations are greater than the reporting limit, the associated data will be labeled with a *U* (in essence, increasing the reporting limit for the affected samples), and associated project samples within five times the *de facto* reporting limit will be flagged with a *J* (Grepogrove 2007). In such cases, the *de facto* reporting limit for that analyte will be recorded along with the raw data, equipment will be decontaminated, and samples will be reanalyzed if possible.

Reporting Limits

Both raw values and reporting limits will be presented in each laboratory report. If the proposed reporting limits are not met by the laboratory, the laboratory will be requested to reanalyze the samples and/or revise the method, if time permits. Proposed reporting limits for this project are summarized in Table 2.

Duplicates

Duplicate results exceeding the MQOs for this project (see Table 1) will be recorded in the raw data tables, as well as noted in the quality assurance worksheets; associated values will be flagged as estimates (*J*). If the objectives are severely exceeded (e.g., more than twice the objective), then the associated value(s) will be rejected (*R*).

Matrix Spikes

Matrix spike results exceeding the MQOs for this project (see Table 1) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (*J*). However, if the percent recovery exceeds 125 percent and a value is less than the reporting limit, the result will not be flagged as an estimate (*J*). Nondetected values will be rejected (*R*) if the percent recovery is less than 30 percent.

Control Standards

Control standard results exceeding the MQOs for this project (see Table 1) will be noted in the quality assurance worksheets, and associated values will be flagged as estimates (*J*). If the objectives are severely exceeded (e.g., more than twice the objective), then the associated value(s) will be rejected (*R*).

Data Quality (Usability) Assessment

This section describes the process for determining whether the data meet project objectives once the results are compiled. Data analysis procedures that will be used to meet these objectives are also summarized.

Data Quality Assessment

The Data Quality Assurance Officer will conduct a semiannual, independent review of the quality control data in accordance with the MQOs identified in this QAPP (see Table 1). Based on these reviews, semiannual quality assurance memoranda will be prepared to summarize quality control results, identify when data quality objectives were not met, and describe the resulting limitations, if any, on the use or interpretation of the data. Information to be noted in the quality assurance memorandum includes the following:

- Changes in the quality assurance project plan
- Results of performance and/or system audits
- Significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the MQOs were met, and the resulting impact (if any) on decision-making
- Limitations on use of the measurement data.

These quality assurance memoranda will establish the usability of data and will be included as an appendix to the semiannual data reports for each water year.

Procedures for Data Analysis

The sections below present data analysis procedures that will be used to evaluate flow control and water quality treatment performance of the vegetated roof, and flow control performance of the permeable pavement basketball court at the study site.

Flow Control Performance

Separate data analyses will be performed to assess flow control performance of the LID features at the study site with regard to reducing runoff volumes, peak discharge rates, and flow durations based on the following comparisons. To conduct these analyses, the following information will be compiled for each storm event that occurs during the monitoring period:

- Storm precipitation depth
- Storm duration
- Storm average intensity
- Storm peak intensity
- Storm antecedent dry period
- Peak discharge rate at each monitoring station
- Runoff volume at each station
- Flow duration at each station.

Once this information is compiled, additional analyses will be performed to identify a subset of storms that had sufficient precipitation totals and/or intensities to produce runoff. Specifically, any storm that produced a measurable discharge volume from the impermeable pavement basketball court or metal roof will be flagged as runoff-producing.

Data collected from the impermeable and permeable pavement basketball courts and the traditional and vegetated roofs will be area weighted to facilitate direct comparisons of runoff volumes (cf), peak discharge rates (cfs), and flow durations (h).

Statistical analyses will be performed on the data from the runoff-producing storms to compare hydrologic characteristics (i.e., runoff volumes, peak discharge, flow duration) between the LID features and their paired traditional features. The specific null hypotheses (H_o) and alternative hypotheses (H_a) for these analyses are as follows:

Hypothesis 1:

H_o: Runoff volumes for the permeable pavement basketball court are equal to or higher than those for the impermeable pavement basketball court.

H_a: Runoff volumes for the permeable pavement basketball court are lower than those for the impermeable pavement basketball court.

Hypothesis 2:

H_o: Peak discharge rates for the permeable pavement basketball court are equal to or higher than those for the impermeable pavement basketball court.

H_a: Peak discharge rates for the permeable pavement basketball court are lower than those for the impermeable pavement basketball court.

Hypothesis 3:

H_o: Flow durations for the permeable pavement basketball court are equal to or higher than those for the impermeable pavement basketball court.

H_a: Flow durations for the permeable pavement basketball court are lower than those for the impermeable pavement basketball court.

Hypothesis 4:

H_o: Runoff volumes for the vegetated roof are equal to or higher than those for the metal roof.

H_a: Runoff volumes for the vegetated roof are lower than those for the metal roof.

Hypothesis 5:

H_o: Peak discharge rates for the vegetated roof are equal to or higher than those for the metal roof.

H_a: Peak discharge rates for the vegetated roof are lower than those for the metal roof.

Hypothesis 6:

H_o: Flow durations for the vegetated roof are equal to or higher than those for the metal roof.

H_a: Flow durations for the vegetated roof are lower than those for the metal roof.

To evaluate these hypotheses, a Wilcoxon signed rank test (Helsel and Hirsch 1992) will be used to compare performance data from each paired monitoring station. The Wilcoxon test is a nonparametric analogue to the paired (1-sample) t-test. Through the use of a paired test, differences in the performance data for each monitoring station can be more efficiently assessed, because the noise (or variance) associated with monitoring over a range of storm sizes is blocked out of the statistical analyses (Helsel and Hirch 1992). In all tests, statistical significance will be assessed based on an alpha (α) level of 0.05.

Graphs will be generated from the data to compare hydrologic data from each station over storms of varying magnitude. Scatter plots will be generated to display how performance varies with different storm precipitation totals and average storm intensities. To aid in the interpretation of these plots, separate lines will be fitted to the data for each monitoring station using the locally weighted scatter plot smoothing (LOWESS) method (Helsel and Hirsch 1992). Rainfall–runoff curves will also be generated for each monitored feature. In addition, box plots will be generated to represent the amount of variability at each monitoring station, as well as the significance of differences between stations.

Water Quality Treatment Performance

Similar to the analysis of flow control performance described above, data analyses will be performed to evaluate the performance of water quality treatment of the vegetated roof and metal roof on the study site. Treatment performance in these analyses will be evaluated based on pollutant concentrations measured at each monitoring station.

Statistical analyses will be performed to assess the significance of differences in pollutant concentrations between the vegetated roof and metal roof. The specific null hypothesis (H_o) and alternative hypothesis (H_a) for these analyses are as follows:

H_o: Pollutant concentrations for the vegetated roof are equal to or higher than those for the metal roof.

H_a: Pollutant concentrations for the vegetated roof are lower than those for the metal roof.

To evaluate these hypotheses, a Wilcoxon signed rank test (as described above for the evaluation of flow control) will be used to compare pollutant concentrations measured at each station. Separate tests will be run for all monitoring parameters listed in the *Sampling Process Design* section, except hardness. (Hardness data will only be used in these analyses to compare the data for dissolved copper and zinc to state surface water quality standards.) In all of these tests, statistical significance will be assessed based on an alpha (α) level of 0.05.

Results of the data analyses will be presented in the quality assurance memoranda described previously.

Non-detect Management

The pollutant generating surfaces monitored for this project are not expected to export high concentrations of target pollutants. Consequently, the data set may contain a significant number of samples with constituent concentrations at or below the laboratory reporting limit (i.e., non-detects or censored data). If less than 10 percent of the samples are censored then censored data will be substituted with one-half the detection limit before any data analysis or presentation. If more than 10 percent of the samples are censored then Kaplan–Meier survival analysis will be used to calculate descriptive statistics (e.g., mean, median, standard deviation) and hypothesis testing will be performed after all data at or below the highest reporting limit are set to a constant (example: -1) (Helsel 2005).

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APPENDIX A

Detailed Project Budget

HERRERA ENVIRONMENTAL CONSULTANTS

Cost Estimate for Grass Lawn Partk LID Stormwater Monitoring
Herrera Proposal or Project No. 07-03687-000

Grass Lawn Park LID Stormwater Monitoring
Number of Tasks: 5

	Task 1.0	Task 2.0	Task 3.0	Task 4.0	Task 5.0	Task 6.0	Task PM	TOTAL
	Monitoring Program Design and QAPP	*Equipment Installation, Support, and Training*	*Hydrologic Monitoring*	*Water Quality Monitoring*	*Data Quality Review and Analysis*	*Reporting*	*Project Management / Contract Administration*	
COST SUMMARY								
Labor	$8,562	$6,031	$5,935	$1,003	$9,107	$13,076	$4,281	$47,993
Travel and per diem	$0	$23	$70	$47	$0	$0	$0	$140
Other direct costs (ODCs)	$0	$9,347	$0	$0	$0	$0	$0	$9,347
Subconsultants	$3,864	$660	$15,141	$7,428	$0	$0	$0	$27,093
Analytical laboratory	$0	$0	$0	$5,408	$0	$0	$0	$5,408
GRAND TOTAL	**$12,426**	**$16,061**	**$21,146**	**$13,885**	**$9,107**	**$13,076**	**$4,281**	**$89,981**

COST ITEMIZATION

Labor (2007 rates)

	Personnel		Rate/Hour	Task 1.0 Hours	Task 1.0 Cost	Task 2.0 Hours	Task 2.0 Cost	Task 3.0 Hours	Task 3.0 Cost	Task 4.0 Hours	Task 4.0 Cost	Task 5.0 Hours	Task 5.0 Cost	Task 6.0 Hours	Task 6.0 Cost	Task PM Hours	Task PM Cost	TOTAL Hours	TOTAL Cost
P7	Trial, Walter	Executive Principal Scientist	$64.00	3	$192	0	$0	0	$0	0	$0	0	$0	6	$384	0	$0	9	$576
P4	Lenth, John	Senior Scientist	$42.50	12	$510	3	$128	0	$0	0	$0	12	$510	12	$510	0	$0	39	$1,658
P2	Ahearn, Dylan	Staff Scientist	$32.50	40	$1,300	25	$813	48	$1,560	0	$0	55	$1,788	65	$2,113	32	$1,040	265	$8,613
P2	Catarra, Gina	Staff Scientist	$25.00	0	$0	0	$0	0	$0	0	$0	16	$400	0	$0	0	$0	16	$400
P1	Christensen, Niklas	Engineer	$24.75	0	$0	32	$792	8	$198	12	$297	0	$0	0	$0	0	$0	52	$1,287
F6	Wood, Theresa	Contract Principal	$46.00	0	$0	0	$0	0	$0	0	$0	0	$0	0	$0	4	$184	4	$184
P4	Sophos, Christine	Senior Technical Editor	$31.50	8	$252	0	$0	0	$0	0	$0	0	$0	16	$504	0	$0	24	$756
P2	Magdasy, Bret	Staff CAD/GIS	$26.00	2	$52	0	$0	0	$0	0	$0	0	$0	2	$52	0	$0	4	$104
A4	Bolton, Rhoda	Senior Administrative Coordinator	$26.00	4	$104	0	$0	0	$0	0	$0	0	$0	2	$52	0	$0	6	$156
A3	Wadkins, Shannon	Administrative Coordinator	$22.00	2	$44	2	$44	0	$0	0	$0	0	$0	4	$88	2	$44	10	$220
A2	Robertson, Jeanne	Administrative Staff	$21.35	6	$128	2	$43	0	$0	0	$0	0	$0	8	$171	0	$0	16	$342
	Subtotal Direct Labor			77	$2,582	64	$1,819	56	$1,758	12	$297	83	$2,698	115	$3,873	38	$1,268	445	$14,295
	Labor Overhead (OH) @		188.34%		$4,863		$3,425		$3,311		$559		$5,080		$7,295		$2,388		$26,922
	Fee on Burdened Labor @		15%		$1,117		$787		$760		$128		$1,167		$1,675		$548		$6,183
	Escalation factor on labor @ 0-6% (by task)		0-6%	0%	$0	0%	$0	6%	$105	6%	$18	6%	$162	6%	$232	6%	$76		$594
	SUBTOTAL LABOR (Direct Labor+OH+Fee)				**$8,562**		**$6,031**		**$5,935**		**$1,003**		**$9,107**		**$13,076**		**$4,281**		**$47,993**

TRAVEL AND PER DIEM COSTS	Unit	Cost	Task 1.0 Units	Task 1.0 Cost	Task 2.0 Units	Task 2.0 Cost	Task 3.0 Units	Task 3.0 Cost	Task 4.0 Units	Task 4.0 Cost	Task 5.0 Units	Task 5.0 Cost	Task 6.0 Units	Task 6.0 Cost	Task PM Units	Task PM Cost	TOTAL Units	TOTAL Cost
Auto Use	Mile	$0.485	0	$0.00	48	$23.28	144	$69.84	96	$46.56	0	$0.00	0	$0.00	0	$0.00	288	$140
SUBTOTAL TRAVEL AND PER DIEM				**$0**		**$23**		**$70**		**$47**		**$0**		**$0**		**$0**		**$140**

OTHER DIRECT COSTS (ODCs)	Unit	Cost	Task 1.0 Units	Task 1.0 Cost	Task 2.0 Units	Task 2.0 Cost	Task 3.0 Units	Task 3.0 Cost	Task 4.0 Units	Task 4.0 Cost	Task 5.0 Units	Task 5.0 Cost	Task 6.0 Units	Task 6.0 Cost	Task PM Units	Task PM Cost	TOTAL Units	TOTAL Cost
Field Equipment and Supplies																		
CR800 datalogger	unit	$990	0	$0.00	2	$1,980.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	2	$1,980
COM220 phone modem	unit	$355	0	$0.00	2	$710.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	2	$710
TB4-L60 rain gauge	unit	$887	0	$0.00	1	$886.60	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$887
CM100 rain gauge leveling base	unit	$68	0	$0.00	2	$136.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	2	$136
Weir insert 8 inch	unit	$216	0	$0.00	4	$864.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	4	$864
Druck 1830 transducers	unit	$820	0	$0.00	4	$3,280.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	4	$3,280
Software	unit	$300	0	$0.00	1	$300.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$300
Weather resistent enclosure	unit	$270	0	$0.00	2	$540.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	2	$540
Phone modem switch	unit	$100	0	$0.00	1	$100.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$100
Phone line surge protector	unit	$25	0	$0.00	2	$50.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	2	$50
Phone line monthly charge	month	$0	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0
Misc intallation hardware	unit	$500	0	$0.00	1	$500.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	0	$0.00	1	$500
SUBTOTAL ODCs				**$0**		**$9,347**		**$0**		**$0**		**$0**		**$0**		**$0**		**$9,347**

SUBCONSULTANT COSTS	Unit	Cost	Task 1.0 Units	Task 1.0 Cost	Task 2.0 Units	Task 2.0 Cost	Task 3.0 Units	Task 3.0 Cost	Task 4.0 Units	Task 4.0 Cost	Task 5.0 Units	Task 5.0 Cost	Task 6.0 Units	Task 6.0 Cost	Task PM Units	Task PM Cost	TOTAL Units	TOTAL Cost
Keith Fabing Inc.			0	$3,864.00	0	$660.00	0	$15,141.00	0	$7,428.00	0	$0.00	0	$0.00	0	$0.00	0	$27,093
SUBTOTAL SUBCONSULTANT				**$3,864**		**$660**		**$15,141**		**$7,428**		**$0**		**$0**		**$0**		**$27,093**

ANALYTICAL LABORATORY COSTS	Unit	Cost	Task 1.0 Units	Task 1.0 Cost	Task 2.0 Units	Task 2.0 Cost	Task 3.0 Units	Task 3.0 Cost	Task 4.0 Units	Task 4.0 Cost	Task 5.0 Units	Task 5.0 Cost	Task 6.0 Units	Task 6.0 Cost	Task PM Units	Task PM Cost	TOTAL Units	TOTAL Cost
AM Test Laboratories																		
TSS	sample	$12	0	$0.00	0	$0.00	0	$0.00	40	$480.00	0	$0.00	0	$0.00	0	$0.00	40	$480
Hardness	sample	$10	0	$0.00	0	$0.00	0	$0.00	40	$384.00	0	$0.00	0	$0.00	0	$0.00	40	$384
Total Cu and Zn	sample	$16	0	$0.00	0	$0.00	0	$0.00	40	$640.00	0	$0.00	0	$0.00	0	$0.00	40	$640
Dissolved Cu and Zn	sample	$16	0	$0.00	0	$0.00	0	$0.00	40	$640.00	0	$0.00	0	$0.00	0	$0.00	40	$640
TP	sample	$12	0	$0.00	0	$0.00	0	$0.00	40	$480.00	0	$0.00	0	$0.00	0	$0.00	40	$480
SRP	sample	$10	0	$0.00	0	$0.00	0	$0.00	40	$384.00	0	$0.00	0	$0.00	0	$0.00	40	$384
TKN	sample	$24	0	$0.00	0	$0.00	0	$0.00	40	$960.00	0	$0.00	0	$0.00	0	$0.00	40	$960
NO3+NO2	sample	$16	0	$0.00	0	$0.00	0	$0.00	40	$640.00	0	$0.00	0	$0.00	0	$0.00	40	$640
Fecal Coliform	sample	$20	0	$0.00	0	$0.00	0	$0.00	40	$800.00	0	$0.00	0	$0.00	0	$0.00	40	$800
SUBTOTAL LABORATORY				**$0**		**$0**		**$0**		**$5,408**		**$0**		**$0**		**$0**		**$5,408**

APPENDIX B

Quality Assurance Forms

FIELD LOG SHEET

Field Staff:_________________________ Site:____________________________ Weather:____________________

Maintenance Visit

Date/Time:

Station Name:
Logger Time Correct? ______________________
Gauge Level: ______________________
Measured Level: ______________________
Weir Obstructed? ______________________
Rain Gauge Obstructed? ______________________
Rain Gauge Calibrated? ______________________
Logger Desiccant: ______________________
Notes:

Station Name:
Logger Time Correct? ______________________
Gauge Level: ______________________
Measured Level: ______________________
Weir Obstructed? ______________________
Rain Gauge Obstructed? ______________________
Rain Gauge Calibrated? ______________________
Logger Desiccant: ______________________
Notes:

Station Name:
Logger Time Correct? ______________________
Gauge Level: ______________________
Measured Level: ______________________
Weir Obstructed? ______________________
Rain Gauge Obstructed? ______________________
Rain Gauge Calibrated? ______________________
Logger Desiccant: ______________________
Notes:

Station Name:
Logger Time Correct? ______________________
Gauge Level: ______________________
Measured Level: ______________________
Weir Obstructed? ______________________
Rain Gauge Obstructed? ______________________
Rain Gauge Calibrated? ______________________
Logger Desiccant: ______________________
Notes:

Storm Sampling Visit

Date/Time:

Station Name:
Sample Collected? ______________________
Field Filtered? ______________________
Odor/Color: ______________________
Date/Time Mailed: ______________________
Notes:

Station Name:
Sample Collected? ______________________
Field Filtered? ______________________
Odor/Color: ______________________
Date/Time Mailed: ______________________
Notes:

Station Name:
Sample Collected? ______________________
Field Filtered? ______________________
Odor/Color: ______________________
Date/Time Mailed: ______________________
Notes:

Station Name:
Sample Collected? ______________________
Field Filtered? ______________________
Odor/Color: ______________________
Date/Time Mailed: ______________________
Notes:

Data Quality Assurance Worksheet

By ______________________

Project Name/No./Client: ______________________ Date __________ Page ____ of ____

Laboratory/Parameters: ______________________ Checked: initials __________

Sample Date/Sample ID: ______________________ date __________

Parameter	Completeness/ Methodology	Holding Times	Blanks/ Detection Limit	Matrix Spikes/ Surrogate Recoveries	Lab Duplicates	Field Duplicates	Lab Control Samples	Instrument Calibration/ Performance	ACTION

Automated Data Collection Quality Assurance Worksheet

By ______________________

Project Name/No./Client: ______________________ Date ____________ Page ____ of ____

Site Name/Location: ______________________ Checked: initials ____________

Site Sensor(s): ______________________ date ____________

Sensor	Data Upload Time Span	Data Gaps		Data Anomalies	
		Description/Time Span	Corrective Action	Description/Time Span	Corrective Action

NOTES:

APPENDIX C

Equipment Specifications

CR800-series Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that you confirm system configuration and critical specifications with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE
10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS
3 differential (DF) or 6 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM25T multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. **Resolution of DF measurements with input reversal is half the Basic Res.**

	Input Referred Noise Voltage	
Input Range (mV)[1]	*DF Res (μV)*[2]	*Basic Res (μV)*
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ~9% exists on all ranges to guarantee that full-scale values will not cause over-range.

[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range; digital resolution dominates for higher ranges.

250 μs Integration:	0.34 μV RMS
50/60 Hz Integration:	0.19 μV RMS

MINIMUM TIME BETWEEN VOLTAGE MEASUREMENTS: Includes the measurement time and conversion to engineering units. For voltage measurements, the CR800-series integrates the input signal for 0.25 ms or a full 16.66 ms or 20 ms line cycle for 50/60 Hz noise rejection. DF measurements with input reversal incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors and therefore take twice as long.

250 μs Analog Integration:	~1 ms SE
1/60 Hz Analog Integration:	~20 ms SE
1/50 Hz Analog Integration:	~25 ms SE

COMMON MODE RANGE: ±5 V

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

ANALOG OUTPUTS
2 switched voltage, active only during measurement, one at a time.

RANGE AND RESOLUTION: Voltage outputs programmable between ±2.5 V with 0.67 mV resolution.

ACCURACY: ±(0.06% of setting + 0.8 mV), 0° to 40°C
±(0.12% of setting + 0.8 mV), -25° to 50°C
±(0.18% of setting + 0.8 mV), -55° to 85°C (-XT only)

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS
MEASUREMENT TYPES: The CR800-series provides ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation using any of the 3 switched voltage excitations eliminates dc errors.

RATIO ACCURACY[3]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error.

±(0.04% of voltage reading + offset)/V_x

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

Offset values are reduced by a factor of 2 when excitation reversal is used.

PERIOD AVERAGING MEASUREMENTS
The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution). Any of the 6 SE analog inputs can be used for period averaging. Signal limiting are typically required for the SE analog channel.

INPUT FREQUENCY RANGE:

Input Range	*Signal (peak to peak)*[4] *Min*	*Max*	*Min. Pulse W.*	*Max*[5] *Freq.*
±2500 mV	500 mV	10 V	2.5 μs	200 kHz
±250 mV	10 mV	2 V	10 μs	50 kHz
±25 mV	5 mV	2 V	62 μs	8 kHz
±2.5 mV	2 mV	2 V	100 μs	5 kHz

[4]The signal is centered at the datalogger ground.

[5]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

PULSE COUNTERS
Two 24-bit inputs selectable for switch closure, high frequency pulse, or low-level ac.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 μs time constant.

LOW LEVEL AC MODE: Internal ac coupling removes dc offsets up to ±0.5 V.

Input Hysteresis: 16 mV @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	*Range (Hz)*
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS
4 ports software selectable, as binary inputs or control outputs. They also provide edge timing, subroutine interrupts/wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UART), SDI-12 communications, and SDM communications.

HIGH FREQUENCY MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V
One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT
Control ports 1 and 3 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE
STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

CPU AND INTERFACE
PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS
VOLTAGE: 9.6 to 16 Vdc

TYPICAL CURRENT DRAIN:
Sleep Mode: ~0.6 mA
1 Hz Scan (60 Hz rejection)
w/RS-232 communication: 19 mA
w/o RS-232 communication: 4.2 mA
1 Hz Scan (250 μs integration)
w/RS-232 communication: 16.7 mA
w/o RS-232 communication: 1 mA
100 Hz Scan (250 μs integration)
w/RS-232 communication: 27.6 mA
w/o RS-232 communication: 16.2 mA

CR1000KD OR CR850'S ON-BOARD KEYBOARD DISPLAY CURRENT DRAIN:
Inactive: negligible
Active w/o backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal; reverse polarity protected.

PHYSICAL SPECIFICATIONS
DIMENSIONS: 9.5" x 4.1" x 2" (24.1 x 10.4 x 5.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 1.5 lbs (0.7 kg)

WARRANTY
Three years against defects in materials and workmanship.

CR1000 Specifications

Electrical specifications are valid over a -25° to +50°C range unless otherwise specified; non-condensing environment required. To maintain electrical specifications, Campbell Scientific recommends recalibrating dataloggers every two years. We recommend that the system configuration and critical specifications are confirmed with Campbell Scientific before purchase.

PROGRAM EXECUTION RATE

10 ms to 30 min. @ 10 ms increments

ANALOG INPUTS

8 differential (DF) or 16 single-ended (SE) individually configured. Channel expansion provided by AM16/32 and AM25T multiplexers.

RANGES and RESOLUTION: Basic resolution (Basic Res) is the A/D resolution of a single conversion. **Resolution of DF measurements with input reversal is half the Basic Res.**

Input Range (mV)[1]	Input Referred Noise Voltage DF Res (μV)[2]	Basic Res (μV)
±5000	667	1333
±2500	333	667
±250	33.3	66.7
±25	3.33	6.7
±7.5	1.0	2.0
±2.5	0.33	0.67

[1]Range overhead of ~9% exists on all ranges to guarantee that full-scale values will not cause over-range.

[2]Resolution of DF measurements with input reversal.

ACCURACY[3]:
±(0.06% of reading + offset), 0° to 40°C
±(0.12% of reading + offset), -25° to 50°C
±(0.18% of reading + offset), -55° to 85°C

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

INPUT NOISE VOLTAGE: For DF measurements with input reversal on ±2.5 mV input range; digital resolution dominates for higher ranges.

250 μs Integration: 0.34 μV RMS
50/60 Hz Integration: 0.19 μV RMS

MINIMUM TIME BETWEEN VOLTAGE MEASUREMENTS: Includes the measurement time and conversion to engineering units. For voltage measurements, the CR1000 integrates the input signal for 0.25 ms or a full 16.66 ms or 20 ms line cycle for 50/60 Hz noise rejection. DF measurements with input reversal incorporate two integrations with reversed input polarities to reduce thermal offset and common mode errors and therefore take twice as long.

250 μs Analog Integration: ~1 ms SE
1/60 Hz Analog Integration: ~20 ms SE
1/50 Hz Analog Integration: ~25 ms SE

COMMON MODE RANGE: ±5 V

DC COMMON MODE REJECTION: >100 dB

NORMAL MODE REJECTION: 70 dB @ 60 Hz when using 60 Hz rejection

SUSTAINED INPUT VOLTAGE W/O DAMAGE: ±16 Vdc max.

INPUT CURRENT: ±1 nA typical, ±6 nA max. @ 50°C; ±90 nA @ 85°C

INPUT RESISTANCE: 20 Gohms typical

ACCURACY OF BUILT-IN REFERENCE JUNCTION THERMISTOR (for thermocouple measurements):
±0.3°C, -25° to 50°C
±0.8°C, -55° to 85°C (-XT only)

ANALOG OUTPUTS

3 switched voltage, active only during measurement, one at a time.

RANGE AND RESOLUTION: Voltage outputs programmable between ±2.5 V with 0.67 mV resolution.

ACCURACY: ±(0.06% of setting + 0.8 mV), 0° to 40°C
±(0.12% of setting + 0.8 mV), -25° to 50°C
±(0.18% of setting + 0.8 mV), -55° to 85°C (-XT only)

CURRENT SOURCING/SINKING: ±25 mA

RESISTANCE MEASUREMENTS

MEASUREMENT TYPES: The CR1000 provides ratiometric measurements of 4- and 6-wire full bridges, and 2-, 3-, and 4-wire half bridges. Precise, dual polarity excitation using any of the 3 switched voltage excitations eliminates dc errors.

RATIO ACCURACY[3]: Assuming excitation voltage of at least 1000 mV, not including bridge resistor error.

±(0.04% of voltage reading + offset)/V_x

[3]The sensor and measurement noise are not included and the offsets are the following:

Offset for DF w/input reversal = 1.5·Basic Res + 1.0 μV
Offset for DF w/o input reversal = 3·Basic Res + 2.0 μV
Offset for SE = 3·Basic Res + 3.0 μV

Offset values are reduced by a factor of 2 when excitation reversal is used.

PERIOD AVERAGING MEASUREMENTS

The average period for a single cycle is determined by measuring the average duration of a specified number of cycles. The period resolution is 192 ns divided by the specified number of cycles to be measured; the period accuracy is ±(0.01% of reading + resolution). Any of the 16 SE analog inputs can be used for period averaging. Signal limiting are typically required for the SE analog channel.

INPUT FREQUENCY RANGE:

Input Range	Signal (peak to peak)[4] Min	Max	Min. Pulse W.	Max[5] Freq.
±2500 mV	500 mV	10 V	2.5 μs	200 kHz
±250 mV	10 mV	2 V	10 μs	50 kHz
±25 mV	5 mV	2 V	62 μs	8 kHz
±2.5 mV	2 mV	2 V	100 μs	5 kHz

[4]The signal is centered at the datalogger ground.

[5]The maximum frequency = 1/(Twice Minimum Pulse Width) for 50% of duty cycle signals.

PULSE COUNTERS

Two 24-bit inputs selectable for switch closure, high-frequency pulse, or low-level AC.

MAXIMUM COUNTS PER SCAN: 16.7×10^6

SWITCH CLOSURE MODE:
Minimum Switch Closed Time: 5 ms
Minimum Switch Open Time: 6 ms
Max. Bounce Time: 1 ms open w/o being counted

HIGH-FREQUENCY PULSE MODE:
Maximum Input Frequency: 250 kHz
Maximum Input Voltage: ±20 V
Voltage Thresholds: Count upon transition from below 0.9 V to above 2.2 V after input filter with 1.2 μs time constant.

LOW-LEVEL AC MODE: Internal AC coupling removes AC offsets up to ±0.5 V.

Input Hysteresis: 16 mV @ 1 Hz
Maximum ac Input Voltage: ±20 V
Minimum ac Input Voltage:

Sine wave (mV RMS)	Range (Hz)
20	1.0 to 20
200	0.5 to 200
2000	0.3 to 10,000
5000	0.3 to 20,000

DIGITAL I/O PORTS

8 ports software selectable, as binary inputs or control outputs. C1-C8 also provide edge timing, subroutine interrupts/wake up, switch closure pulse counting, high frequency pulse counting, asynchronous communications (UART), SDI-12 communications, and SDM communications.

HIGH-FREQUENCY PULSE MAX: 400 kHz

SWITCH CLOSURE FREQUENCY MAX: 150 Hz

OUTPUT VOLTAGES (no load): high 5.0 V ±0.1 V; low <0.1

OUTPUT RESISTANCE: 330 ohms

INPUT STATE: high 3.8 to 5.3 V; low -0.3 to 1.2 V

INPUT HYSTERISIS: 1.4 V

INPUT RESISTANCE: 100 kohms

SWITCHED 12 V

One independent 12 V unregulated sources switched on and off under program control. Thermal fuse hold current = 900 mA @ 20°C, 650 mA @ 50°C, 360 mA @ 85°C.

SDI-12 INTERFACE SUPPORT

Control ports 1, 3, 5, and 7 may be configured for SDI-12 asynchronous communications. Up to ten SDI-12 sensors are supported per port. It meets SDI-12 Standard version 1.3 for datalogger mode.

CE COMPLIANCE

STANDARD(S) TO WHICH CONFORMITY IS DECLARED: IEC61326:2002

CPU AND INTERFACE

PROCESSOR: Renesas H8S 2322 (16-bit CPU with 32-bit internal core)

MEMORY: 2 Mbytes of Flash for operating system; 4 Mbytes of battery-backed SRAM for CPU usage, program storage and data storage.

SERIAL INTERFACES: CS I/O port is used to interface with Campbell Scientific peripherals; RS-232 port is for computer or non-CSI modem connection.

PARALLEL INTERFACE: 40-pin interface for attaching data storage or communication peripherals such as the CFM100 module

BAUD RATES: Selectable from 300 bps to 115.2 kbps. ASCII protocol is one start bit, one stop bit, eight data bits, and no parity.

CLOCK ACCURACY: ±3 min. per year

SYSTEM POWER REQUIREMENTS

VOLTAGE: 9.6 to 16 Vdc (reverse polarity protected)

TYPICAL CURRENT DRAIN:
Sleep Mode: ~0.6 mA
1 Hz Scan (8 diff. meas., 60 Hz rej., 2 pulse meas.)
w/RS-232 communication: 19 mA
w/o RS-232 communication: 4.2 mA
1 Hz Scan (8 diff. meas., 250 μs integ., 2 pulse meas.)
w/RS-232 communication: 16.7 mA
w/o RS-232 communication: 1 mA
100 Hz Scan (4 diff. meas., 250 μs integ.)
w/RS-232 communication: 27.6 mA
w/o RS-232 communication: 16.2 mA

CR1000KD CURRENT DRAIN:
Inactive: negligible
Active w/o backlight: 7 mA
Active w/backlight: 100 mA

EXTERNAL BATTERIES: 12 Vdc nominal

PHYSICAL SPECIFICATIONS

MEASUREMENT & CONTROL MODULE SIZE: 8.5" x 3.9" x 0.85" (21.6 x 9.9 x 2.2 cm)

CR1000WP WIRING PANEL SIZE: 9.4" x 4" x 2.4" (23.9 x 10.2 x 6.1 cm); additional clearance required for serial cable and sensor leads.

WEIGHT: 2.1 lbs (1 kg)

WARRANTY

Three years against defects in materials and workmanship.

Tipping Bucket Rain Gages

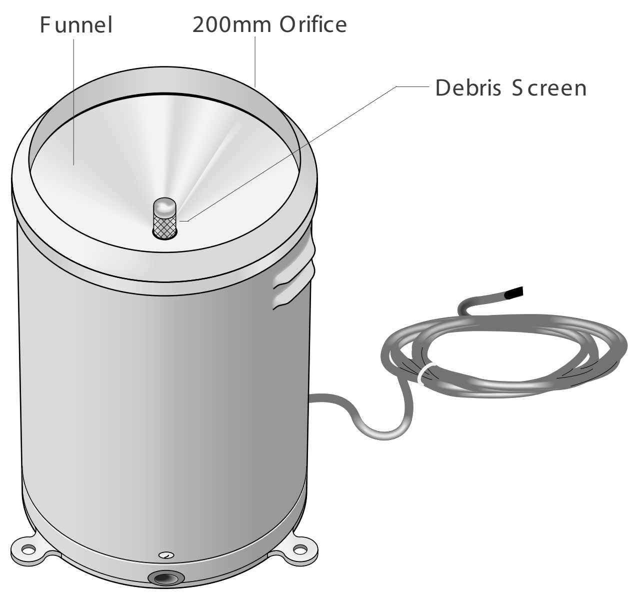
Models TB4 and CS700

The TB4 and CS700 rain gages are manufactured by Hydrological Services Pty. Ltd. For both rain gages, rain funnels into a tipping bucket mechanism that tips when 0.2 mm of rain has been collected. Each tip is marked by a dual reed switch closure that is recorded by a Campbell Scientific datalogger pulse count channel. After measurement, the water drains through two orifices (accepts 12 mm tubing) in the base, allowing the measured water to be collected in a separate container.

TB4 as viewed from above

The rain gages include a siphoning mechanism that allows the rain to flow at a steady rate to the tipping bucket mechanism regardless of rainfall intensity. This reduces typical rain bucket errors and produces accurate measurements over a range of 0 to 700mm/hr^{-1} (27.5"/hr^{-1}) enabling the TB4 and CS700 to record intense rainfall events.

The major difference between the TB4 and CS700 is their base. The TB4 has a UV stabilized plastic base whereas the CS700 has a powder-coated aluminum base.



CS700 as viewed from above

Options

As shipped, the base of the gage is supported by three legs. The CM240 Mounting/Leveling Base or a user-supplied baseplate with leveling capability is recommended. The CM240 requires a user-supplied concrete pad and a 1.5" diameter IPS pipe to mount the gage at the recommended 1 m measurement height.

Ordering Information

TB4-L__	TB4 tipping bucket. Specify lead length (in feet) after the L.
CS700-L__	CS700 tipping bucket. Specify lead length (in feet) after the L.

CAMPBELL SCIENTIFIC CANADA CORP
11564 - 149 street - edmonton - alberta - T5M 1W7
tel 780.454.2505 fax 780.454.2655
www.campbellsci.ca

Specifications

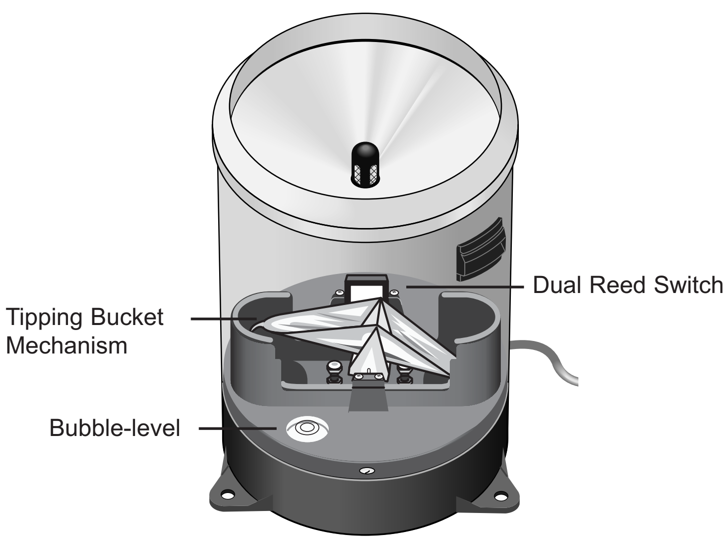
Sensor:	Tipping bucket with siphon
Orifice Diameter:	200 mm (7.9″)
Drain Tube Diameter:	Both filters accept 12 mm ID tubing
Resolution:	0.2 mm
Measurement Range:	0 to 700 mm/hr^{-1} (0 to 27.6″hr^{-1})
Environmental Conditions:	
Temperature:	0° to 70℃
Humidity:	0 to 100%

TB4

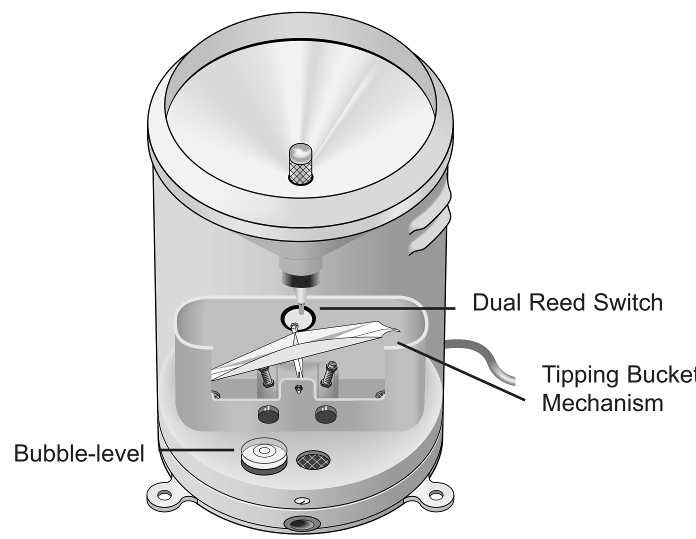
Accuracy:	Better than ±3% b/w 25 to 500 mm/hr^{-1} (1 to 19.7mm hr $^{-1}$)
Weight:	2 kg (4.4 lbs) with 25 ft signal cable (two-conductor shielded)
Height:	33 cm (13")

CS700

Accuracy:	Better than ±2% @ (25 to 500 mm/hr)
Weight:	3.3 kg (7.4 lbs)with 25 ft signal cable (two-conductor shielded)
Height:	34.2 cm (13.5″)



Transparent view of TB4 shows tipping bucket mechanism



Transparent view of CS700 shows tipping bucket mechanism

CAMPBELL SCIENTIFIC
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VOLUMETRIC WEIRS

For measuring flows in Manholes and Open End Pipes

WEIR SET
(refer to back page for details)

15” WEIR WITH 18” ADAPTER

WEIR WITH BUBBLER TUBE

The most practical, economical instrument for testing new sewer lines - night flow studies of existing lines – free flow from open end pipe.

A VOLUMETRIC calibrated weir is a portable flow measuring device that is used to determine infiltration in newly installed sewer lines, or measure substantial flows in existing lines.

THE THEL-MAR VOLUMETRIC weir is basically a compound weir that incorporates the advantage of a 90° V-notch for measuring small infiltration flow where accuracy is of prime importance. The V-notch section measures from 57 gallons to 3700 gallons per 24 hours, which is the range of normal Acceptance Test Requirements. The rectangular section of the weir is capable of measuring in gallons per day up to 35% of pipe capacity.

A BUBBLE LEVEL is mounted at the top of the weir's face plate for easy visibility. Thel-Mar weirs are calibrated in U.S. GALLONS PER 24 HOURS (METRIC WEIRS CUBIC METERS PER HOUR) in large, easy to read type. Calibration lines are in 2 millimeter increments.

DISCHARGE CALIBRATIONS for the Volumetric Weir were accurately determined in a hydraulic laboratory where manhole conditions were duplicated. Therefore, there are no induced errors by insufficient drop of the nappe or by contractions, velocity of approach, submergency, or drawdown.

RUGGED CONSTRUCTION and noncorroding materials make the Thel-Mar weir extremely reliable. There are no loose parts that require assembly. Installation is quick and positive and the weir requires a minimum of care.

A COMPOUND WEIR offers minimum restriction to flow and is relatively free from becoming clogged by debris from sewage. Thel-Mar weirs can be installed for extended periods of time without accumulation of sediment.

ERRORS IN EXCESS OF 100% exist in other calibrated V-notch weirs. Unlike the Thel-Mar weir these were calibrated by the cone formula.

EASY TO READ FLOW RATE Simply check water level at the face plate. The figure above the line matching the water level gives you the rate of flow in GALLONS PER 24 HOURS (METRIC WEIRS-CUBIC METERS PER HOUR).

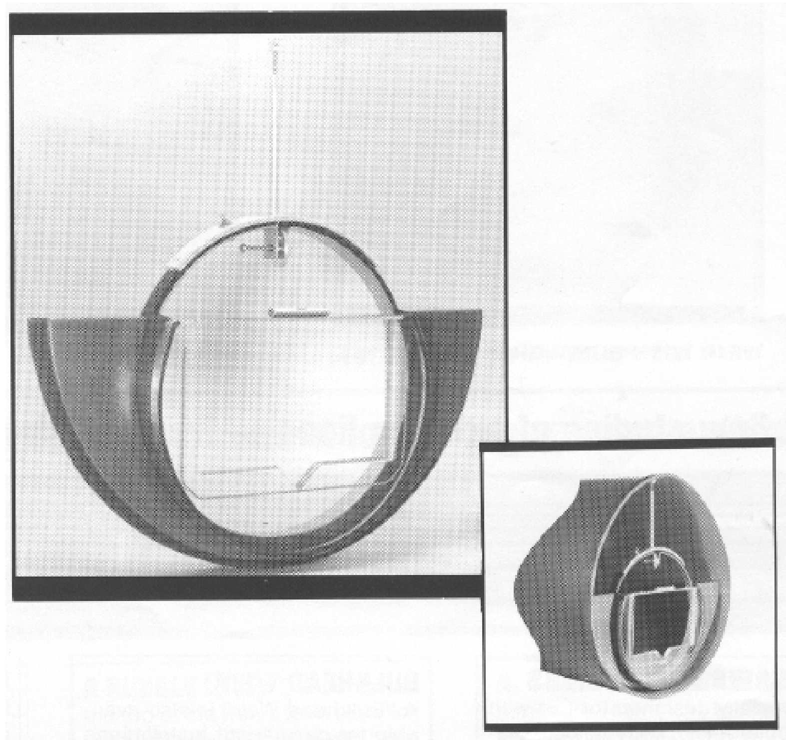
BUBBLER FLOW METERS
Especially designed for use with Bubbler Flow Meters, all Volumetric Weirs are now available with an attached "Bubbler Tube". These weirs are manufactured with a 1/8 inch O.D. stainless steel tube attached to the right side of the adjustable ring. The bubbler tube protrudes forward approximately two inches from near the top of the ring for easy connection to a line. It runs from there down the inside of the ring to approximately 1 3/8-inch behind and below the V-notch. This bubbler tube does not in any way affect the function of the Volumetric Weir.

INSTALLATION INSTRUCTIONS
Prior to installation, the interior edge of the incoming pipe should be cleared of sediment and foriegn matter to assure seal of the gasket.

Turn thumb-wheel to extreme right. Place hand through weir opening, wiht thumb and index finger compress spring. Insert weir into incoming pipe about 1", and release tension from spring. Secure by turning thumb-wheel to left and finger tighten.

Allow sufficient time for water to back up and behind the weir and establish a uniform flow; five to ten minutes for existing flow to an hour for accurate infiltration readings.

15” WEIR WITH ADAPTOR INSTALLED IN 24” PIPE



Individual Volumetric Weirs are available for 6", 8", 10", 12", 14", 15" and 16" pipe. The 14" weir uses a 12" face plate. Adaptors for 18", 21", 24", 27", 30", 36", 42" and 48" pipe are used in conjunction with the 15" weir.

Volumetric Weirs are also available in a set. Set A consists of 6", 8", 10’, 12" and 15" weirs with an 18” adaptor and carrying case with handle and hasp. It measures 191/2"W x 191/2"D x 71/2"H. Set B is similar and designed to be used with Bubbler Flow Meters.

Adaptors are available individually or in a set. Set C consists of 21" through 48" adaptors. No carrying case included.

WEIR CAPACITIES AND HEAD

CAPACITIES*			HEAD**
6"	57 to 3700 GPD within V-notch,	rectangular to 46,000 GPD	2.8437
8"	57 to 3700 GPD within V-notch,	rectangular to 124,000 GPD	4.0000
10"	57 to 3700 GPD within V-notch,	rectangular to 234,000 GPD	5.1250
12"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
14"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
15"	57 to 3700 GPD within V-notch,	rectangular to 610,000 GPD	7.3125
16"	57 to 3700 GPD within V-notch,	rectangular to 610,000 GPD	7.3125
Bulkhead Weir	57 to 3700 GPD within V-notch,	rectangular to 610,000 GPD	7.3125

* Calibration lines are in 2 millimeter increments.
** In inches from top of rectangular opening to bottom of V-notch.

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APPENDIX D

Additional Measurement Quality Objectives Tables

Table D-1. Laboratory control sample recovery criteria for water by solid phase extraction (SPE) (EPA 8270D).

Compound	Minimum Recovery	Maximum Recovery
Naphthalene	52	112
2-Methylnaphthalene	50	119
1-Methylnaphthalene	43	129
Biphenyl	47	130
2-Chloronaphthalene	54	119
Acenaphthylene	59	116
Acenaphthene	55	118
Fluorene	57	115
Phenanthrene	60	108
Anthracene	54	111
Fluoranthene	57	104
Pyrene	55	103
Retene	55	108
Benzo(a)Anthracene	50	108
Chrysene	50	107
Benzo(b)fluoranthene	45	110
Benzo(k)fluoranthene	48	113
Benzo(a)pyrene	49	113
Indeno(1,2,3-cd)pyrene	42	109
Dibenzo(a,h)anthracene	49	109
Benzo(g,h,i)perylene	55	105

Table D-2. Surrogate recovery criteria for water samples to be analyzed for polycyclic aromatic hydrocarbons (EPA 8270D).

Surrogate Compound	% Recovery
2-Fluorophenol	25-121
Phenol-D_5	24-113
2-Chlorophenol-D_4	20-130
1,2-Dichlorobenzene-D_4	20-130
Nitrobenzene-D_5	23-120
2-Fluorobiphenyl	30-115
Pyrene-D_{10}	50-150
Terphenyl-D_{14}	18-137

Table D-3. Matrix spike/spike duplicate recovery criteria for water samples to be analyzed for polycyclic aromatic hydrocarbons (EPA 8270D).

Compound Spiked	RPD (%)	Recovery
Phenol	42	12-110
2-Chlorophenol	40	27-123
N-Nitroso-di-n-propylamine	38	41-116
4-Chloro-3-methylphenol	42	23-97
Acenaphthene	31	46-118
4-Nitrophenol	50	10-80
2,4-Dinitrotoluene	38	24-96
Pentachlorophenol	50	9-103
Pyrene	31	26-127

RPD = relative percent difference